SST

AN ECONOMIC ANALYSIS

Part I. Executive Summary

PRELIMINARY

UNITED STATES DEPARTMENT OF COMMERCE

EXPLANATION OF RELEVANCY OF CONCLUSIONS AND DATA CONTAINED
IN THE SST ECONOMIC ANALYSIS REPORT PREPARED BY THE DEPARTMENT OF COMMERCE

In an effort to provide as complete a history as possible of the course of the SST program, materials consisting of Part I, Executive Summary and Supplements, and Part III, Contractor's Reports*, have been made publicly available. However, all persons using these materials should be advised that the data and conclusions pertaining to the SST designs contained therein are not current and have been superseded by the SST designs submitted to the FAA September 6, 1966, which were the basis for the Economic Feasibility Report prepared by the FAA in April 1967 and for the reports of the Economic Research Contractors submitted December 31, 1966. Using the superseded designs and the related economic data for comparisons with economic characteristics of other aircraft, both American and European, could be misleading and not representative of what was achieved with the more recent SST designs.

Because of the changes in development costs and total program costs and because of the provisions of the Phase III contracts with the airframe and engine manufacturers, the financial data and conclusions contained in the Executive Summary relating to the financial capability of the manufacturers do not reflect their financial capability in the context of the current program or their general financial position.

Accordingly, the materials attached hereto should be viewed as predominately historical in character.

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* Part II of the SST Economic Analysis was never issued.

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U.S. DEPARTMENT OF COMMERCE
WASHINGTON, D.C.

SST

AN ECONOMIC ANALYSIS

Part I
Executive Summary

[redacted]

THE SECRETARY OF COMMERCE
WASHINGTON, D.C. 20230

The President
The White House
Washington, D.C.

Dear Mr. President:

In your memorandum of May 20, 1964, you requested that the Secretary of Commerce conduct systematic economic studies of the Supersonic Transport Program. I have the honor to transmit to you a preliminary report of our studies. This first in a continuing series of reports provides a substantial body of information bearing on the SST Program decision.

The study has been performed by an interagency team under the direction of the Department of Commerce. The cooperating agencies included the following:

Treasury Department
Department of Defense
Civil Aeronautics Board
Federal Aviation Agency
National Aeronautics and Space Administration

The unstinting cooperation provided by these various agencies should not be interpreted necessarily to imply their endorsement of the results of the study. These are solely the responsibility of the Department of Commerce.

I am concurrently forwarding copies of this report to Robert S. McNamara, Secretary of Defense; Najeeb E. Halaby, Administrator, Federal Aviation Agency; and to Kermit Gordon, Director, Bureau of the Budget.

Respectfully yours,

John T. Connor

Secretary of Commerce

Enclosure

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CAPSULE SUMMARY

1. AUTHORITY FOR STUDY

In his memorandum of May 20, 1964 dealing with the Supersonic Transport Program, the President requested the Secretary of Commerce to conduct systematic economic studies to relate different types and sizes of aircraft, including advanced subsonic transports, to actual route structures, future possible fare structures, and the varied operational conditions that the airlines encounter. He further requested the Secretary to work in close coordination with the Federal Aviation Agency and the Civil Aeronautics Board, and to utilize the resources and data available from both.

2. STATEMENT OF THE PROBLEM

In determining how best to proceed with the Supersonic Transport Program, the United States is faced with a major investment decision. A joint public-private program is being considered to develop a supersonic transport (SST) to meet the challenge of the Concorde. The problem, however, is much broader than merely meeting foreign competition. By the mid-1970s, the long-range subsonic aircraft in the fleets of the Free World carriers will be largely based on design concepts some 15 to 20 years old. Moreover, the expected growth in traffic will generate demand for seat-mile capacities significantly greater than those of current fleets. When the requirements for fleet replacement, expansion, and modernization are considered, the need for newer and more productive aircraft designs becomes clear. The Concorde and the American SST designs represent alternative supersonic approaches to providing this increased productivity. Still another approach to increased productivity is by means of an advanced subsonic aircraft based on the commercialization of the military CX-HLS aircraft (now designated C5A). While the Concorde competes directly with the SST, the advanced subsonic aircraft provides both competition and the opportunity for complementary services at low cost.

The President's memorandum and the deliberations of the SST Advisory Committee indicate clearly that the complete range of investment alternatives affecting long-range air transport should be assessed. The problem before the United States may therefore be stated as follows:

> WHICH PROGRAM IS BEST SUITED FOR IMPROVING LONG-RANGE AIR TRANSPORT?

As here denoted, long-range air transport includes all transportation of passengers, cargo, freight, and mail over route distances greater than 900 statute miles. The aircraft productivity needed for serving this market may be achieved through various alternative programs. Success of any program will depend on the price, availability and performance of the resulting aircraft relative to competition; on consumer preferences with respect to fares, trip times, and frequency of service; and, for the supersonic aircraft, on the possibility of restricted operations of airlines because of sonic boom.

3. POLICY ISSUES: PACE, COMPETITION, AND RISK-SHARING

3.1 POLICY GUIDANCE

A general statement of policy as to the choice among alternative programs is that given in the President's 1962 Message on Transportation to the Congress, as follows:

> "The basic objective of our nation's transportation system must be to assure the availability of the fast, safe and economical transportation services needed in a growing and changing economy to move people and goods, without waste or discrimination, in response to private and public demands at the lowest cost consistent with health, convenience, national security and other broad public objectives. Investment or capacity should be neither substantially above nor substantially below these requirements—for chronic excess capacity involves misuse of resources, and lack of adequate capacity jeopardizes progress. The resources devoted to provision of transportation service should be used in the most effective and efficient manner possible; and this, in turn, means that users of transport facilities should be provided with incentives to use whatever form of transportation which provides them with the service they desire at the lowest total cost, both public and private."

Further, the policy contemplates both private and public investment in facilities, and specifies that, to the extent possible, users cover full costs in order that transportation services may be used in the most effective and efficient manner. The emphasis is clearly upon the economic aspects of the system, provided that the requirements of health, convenience, national security and other broad public objectives are met. What is "best" for the United States must then be determined through a balancing among a number of possibly conflicting objectives.

3.2 ENVIRONMENT FOR SST PROGRAM DECISION

In determining whether the SST Program is well suited for improving long-range air transport, the SST Advisory Committee must consider the future environments which may exist and the time phasing of the various decisions which may be made. A decision for continuing with the SST Program requires Government and private initiative in 1965; that for producing the commercial CX-HLS awaits private initiative later in this decade, possibly in 1968. The British and French have recently decided to continue with the Concorde, at least until completion of a prototype.

The four environments which could then arise as a result of future decisions, here and abroad, are as follows:

Environments and Decisions

		SST	
Concorde	Commercial CX-HLS	Action	Timing
Continued into production	Not initiated in 1968	?	1965
Continued into production	Initiated in 1968	?	1965
Terminated after prototype	Not initiated in 1968	?	1965
Terminated after prototype	Initiated in 1968	?	1965

The course of action for the SST Program which is selected in 1965 must provide a suitable U.S. posture, or be capable of later modification so as to be suitable, no matter which of these future environments arise.

3.3 POLICY QUESTIONS

The ... icy questions at issue before the Supersonic Transport Advisory Committee are the following:

a. What is the proper pace at which the SST Program should proceed, considering the absolute requirement for flight safety and the competitive threat of the Concorde and the advanced subsonic aircraft?

b. What is the nature and extent of competition between manufacturers that is needed in the SST Program to protect the public interest and to yield the greatest return on program investment? When the long view is taken (from the time of decision for rapid development until retirement of the last SST), might competition during development and production lead to a more economic aircraft, and hence, to a greater return on program investment?

c. What risk-sharing arrangements between the public and private sectors are best suited for the timely and effective implementation of the SST Program, and also consistent with the need for preserving private initiative?

Implicit here is the need for considering many interrelated factors in arriving at a sound program decision.

Choices as to Pace and Competition

While many variations are possible, there are basically four alternatives for action at this time:

a. Choose one manufacturing team (airframe and engine) now; aim for first in-service delivery of the SST in 1972.

b. Foster competition during development by choosing one manufacturing team after flight test; aim for first in-service delivery in 1972.

c. Choose now; aim for 1974. The term, 1974, is used only as an adjective denoting a more deliberately paced program.

d. Choose after flight test; aim for 1974.

Choices as to Risk-sharing

Clearly inseparable from the issues of pace and competition are the arrangements for sharing risks. The choices here relate to the nature, timing, and extent of government support (hence, control) appropriate in the public interest, and involve the management of the program as well as its financing. Each of the many possible arrangements will affect the aircraft manufacturing and air transport industries in a different way, and hence alter their ability and willingness to share risks.

Within the wide spectrum of arrangements possible, the four listed in Table 3.1 serve to illustrate certain salient differences in approach. These differences lie in the nature and extent of influence exercised by Government in making the controlling decisions:

Case I — Strong and direct control by Government in every phase of SST Program; subsidy of manufacture and/or operations contingent on success of program.

Case II — Strong and direct control by Government only during development phase of SST Program; no subsidy of manufacture or operations.

Table 3.1. Alternative Approaches to Risk-sharing

Controlling decisions	Approaches			
	Case I	Case II	Case III	Case IV
Development				
Contractor selection	Design competition managed and judged by Government	Design competition managed and judged by Government	Design competition sponsored by Government; judged by private	Private
Product specification				
Product timing				
Sources of funds	Major Government subvention	Intermediate Government subvention	Minor Government subvention	No direct Government subvention
Manufacture				
Scale of production	Contingent Government responsibility	Private	Private	Private
Aircraft pricing				
Sources of funds	Contingent Government subvention	Private	Private	Private
Operations				
Choice of market	Contingent Government responsibility	Private	Private	Private
Air travel pricing	CAB-regulated or influenced	CAB-regulated or influenced	CAB-regulated or influenced	CAB-regulated or influenced
Sources of funds	Contingent Government obligation	Private	Private	Private

Case III — Indirect control by Government only during development phase of SST Program; no subsidy.

Case IV — Strong and direct control by private sector in every phase of SST Program.

Note that some form of Government assistance (direct or indirect) in financing development is common to all four approaches. The nature and extent of such assistance would, of course, vary.

3.4 SUMMARY

A program alternative involves a set of interrelated choices as to aircraft type, program pace, degree of competition among manufacturers, and arrangements for sharing risks between public and private sectors. A decision for continuing with the SST Program requires Government and private initiative in 1965; that for producing the commercial CX-HLS awaits private initiative later in this decade, possibly in 1968.

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4. AIRCRAFT CONSIDERED

The aircraft considered in this study are the following:

a. Subsonic

A current large aircraft, the Boeing 707-320B,

A growth version of the current large aircraft,

A commercial version of the CX-HLS heavy logistics aircraft.

b. Supersonic

The Boeing 733-290 SST,

The Lockheed L2000-2P SST,

The Anglo-French Concorde.

The Lockheed SST was not treated here in a manner comparable to that of the Boeing SST because of its performance deficiencies, as determined by FAA.

In Figure 4.1 are shown the summary characteristics of these aircraft. All are drawn to the same scale, and a silhouette of the current large jet is shown under each for size comparison. More detailed data are provided in the supporting information below. (See Section A1.)

For the international versions (in which the seating arrangement is 10 percent first class, and 90 percent tourist), we note that the current subsonic jet has 161 seats; the growth subsonic, 215 seats; and the commercialized logistics aircraft, approximately 652 seats. Each cruises at a speed of approximately Mach 0.82. The commercial CX-HLS used here has a range of 3400 statute miles at full payload; the other subsonic jets, ranges of at least 4000 miles.

The Boeing 733-290 has 228 seats and cruises at Mach 2.7; the Lockheed L2000-2P, 210 seats and Mach 3.0; the Concorde, 108 seats and Mach 2.2. At full payload, the 733-290 has a range of 3800 statute miles; the L2000-2P, 2300 miles; the Concorde, 3900 miles.

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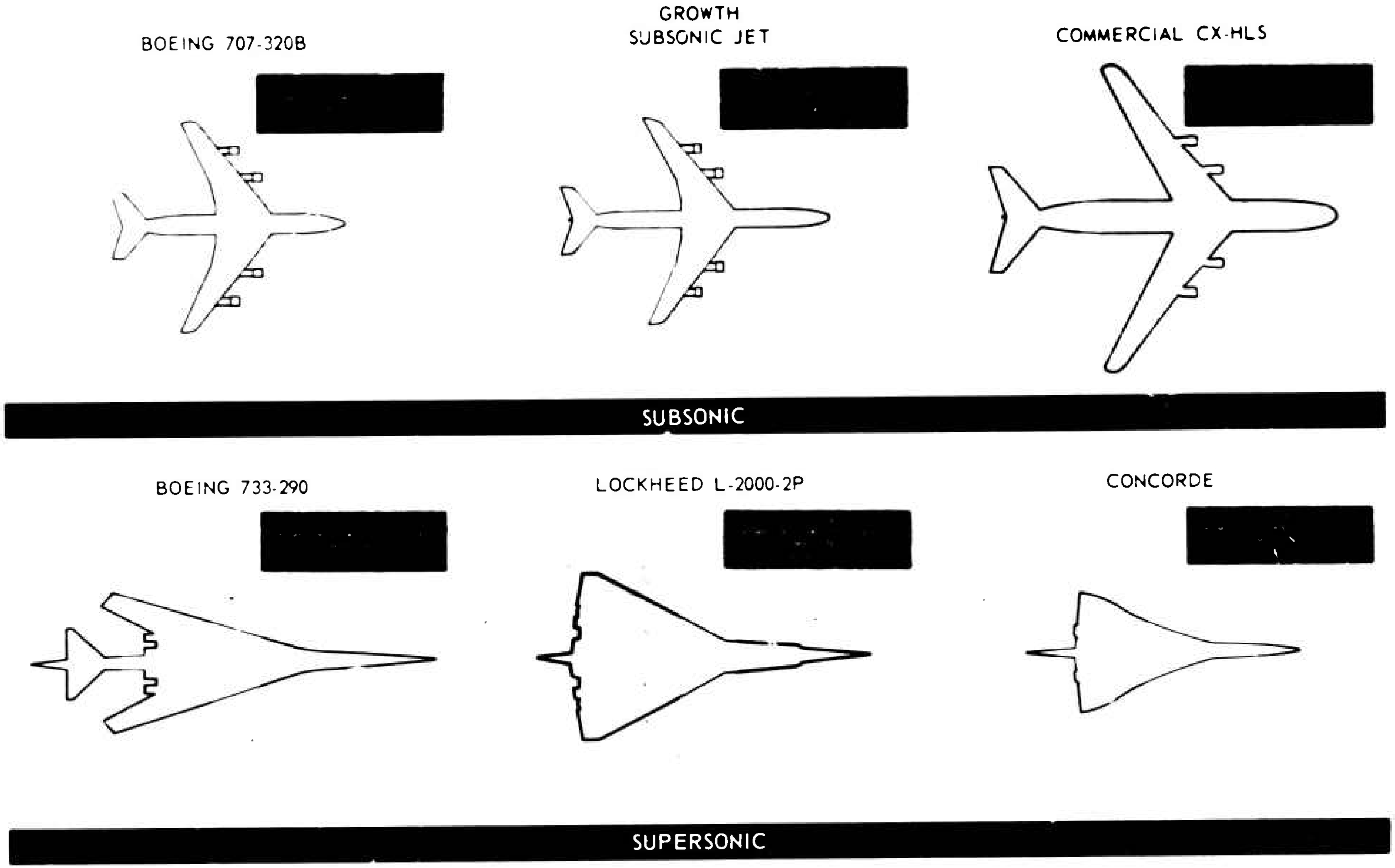

Figure 4.1. Summary characteristics of aircraft considered in study (733-290 and L2000-2P are FAA validated values).

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5. SUMMARY OF RESULTS AND POLICY CONSIDERATIONS

Programs for improving long-range air transport may be based on either of two aircraft types—the SST or the commercial CX-HLS. The decision for continuing with the SST Program requires Government and private initiative in 1965; that for producing the commercial CX-HLS awaits private initiative later in this decade, possibly in 1968. Because of this difference in initiative and timing, the information here presented deals more extensively with the SST than with the commercial CX-HLS.

5.1 TECHNICAL FEASIBILITY

The Boeing 733-290 has been validated as technically feasible by a joint FAA-NASA-DOD team. The commercial CX-HLS may likewise be assumed to be technically feasible since it represents only a moderate extension of current art and the military version is well along in its program definition phase.

Either aircraft can provide the higher productivity (in seat-miles per year) required to meet air transport needs in 1980. The SST provides increased seating capacity and speed at cost levels comparable to those of present aircraft; the CX-HLS provides present speeds but lower cost levels due to greatly increased seating capacity. Both aircraft are highly specialized with respect to the city-pairs which they may serve, both as to route distance and market density.

5.2 1980 REQUIREMENTS FOR AIR TRANSPORT

To meet the need for long-range air transport in 1980, the Free World carriers are expected to purchase a fleet of aircraft having a seat-mile capacity 4 times greater than that in 1964, within a range of 3 to 5. Moreover, the continuing growth is expected to double these fleet requirements between 1980 and 1990.

On the basis of comparative costs to airlines and attractiveness to travelers, it appears likely that the SST could largely displace the current and growth subsonic jets over the 154 principal SST-potential routes. The expected displacement would create a market (1972-1980) for 660 SSTs, within a range of 500 to 860.

If the SST Program were now terminated and the commercial CX-HLS were used exclusively in the 50 markets of greatest density, the expected requirement in 1980 would be for 350 aircraft. Since this aircraft has 4 times the capacity of the current jet and the air transport market is expected to grow 4-fold by 1980, the flight frequencies offered at that time should not differ materially from those at present. The remaining 104 principal markets would presumably then be served by other subsonic jets.

5.3 SONIC BOOM

The economic effects of sonic boom are such as to increase the costs of operation and, possibly, to reduce

[redacted]

revenues through loss of payload and or markets. On the extreme assumption that the SST is restricted to overwater operations, the hard core requirement for aircraft expected in 1980 is 220 SSTs, within a range of 170 to 290. This market can then be expanded up to 660 aircraft (the expected market if boom effects were negligible) depending on the respective willingness of:

a. the carriers to incur the additional costs associated with boom so as to increase their revenues. These costs over U.S. domestic routes are expected to amount to 7 percent of total operating costs, within a range of 2 to 40 percent.

b. the general public to accept higher ambient noise levels.

The wide range in expected additional costs highlights the need for more engineering work to minimize boom generation and more study of socio-political reactions to boom.

5.4 ECONOMIC VIABILITY

Measuring on the basis of internal rate of return on program cash flow[1] (before interest and taxes) and assuming nominal conditions, the competing aircraft—Boeing 733-290, Concorde and commercial CX-HLS—are expected to be economically viable. As shown for the SST in Table 5.1 the returns to U.S. carriers vary markedly with the source of data inputs.

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[1]Average returns on investment to manufacturers generally (before interest and taxes) range from 20 to 40 percent, with the aircraft manufacturers at the lower end of the range; returns to the airlines, 15 to 20 percent on the system and much higher on the better routes.

Table 5.1. Internal Rates of Return on SST Program Cash Flow (before interest and taxes)

Source of data inputs	Percent return on quantity of 200 to	
	Manufacturers	U.S. carriers
Manufacturers	14	71
FAA	14	62
Planning Research Corp. .	14	36
Operations Research, Inc.	13	22

The SST returns assume full amortization of development costs, and 10 percent differential above current subsonic fares. The wide range in these returns reflects the uncertainties in estimation of costs. These returns are quite sensitive to variations in aircraft sales price, fare differential, boom restrictions and load factor.

Under equivalent assumptions and using the currently mentioned price (believed to include little or no development costs), the Concorde is expected to yield returns to U.S. carriers as shown in Table 5.2, where the lower returns reflect the inclusion of development costs into the Concorde price.

Again using equivalent assumptions, the various subsonic aircraft are expected to yield higher returns than the supersonic. At a differential of 10 percent below current subsonic fares, the commercial CX-HLS yields returns as shown in Table 5.3.

Table 5.2. Internal Rates of Return on Concorde to U.S. Carriers (before interest and taxes)

Source of data inputs	Percent return on quantity of 200 to U.S. carriers
Manufacturer	62
Planning Research Corp.	18
Operations Research, Inc.	14

Table 5.3. Internal Rates of Return on Commercial CX-HLS (before interest and taxes)

Source of data inputs	Percent return on quantity of 50 to	
	Manufacturers	U.S. carriers
Manufacturer	37	106
Planning Research Corp. .	45	48
Operations Research, Inc.	40	44

Using manufacturers' data inputs and a differential of 30 percent below current fares, the commercial CX-HLS is expected to yield returns to the carriers comparable to those of the SST at a differential 10 percent above current fares. The high returns for the commercial CX-HLS are attributable to its great seating capacity and to its small incremental cost ($69 millions) for commercialization.

5.5 SST PROGRAM FINANCING

The financial requirements for the SST Program appear to be approximately within the combined availability of funds from the manufacturers and airlines, without major direct Government subvention.

For the purposes of analysis, the requirements for the prototype phase (1965-1969) are distinguished from those for the subsequent certification and production phases. It is during the prototype phase, when design feasibility must be proven, that risks are greatest. Ability to meet program cash requirements by manufacturers and airline has been examined for four patterns of cash flow covering a range of possible corporate policies. These patterns are defined as follows:

a. normal flow, after usual dividends and taxes,

b. normal flow, with cash dividend payout constrained to present 1965 levels, and after taxes,

c. flow with cash dividend constraint, but before Federal income taxes, and

d. an upper limit of availability taken with zero cash dividend payout and before taxes.

As may be seen in Figure 5.1, against a prototype requirement estimated by FAA of $746 million for the Boeing/GE team, the combined cash availability (after providing for non-SST requirements of these manufacturers and of the 13 U.S. trunklines for the period 1965-9) is projected under each of these four patterns as $650 million, $837 million, $2,106 million and $2,516 million, respectively.

For a certification requirement of $446 million, the corresponding cash availabilities during 1970-4 are $613

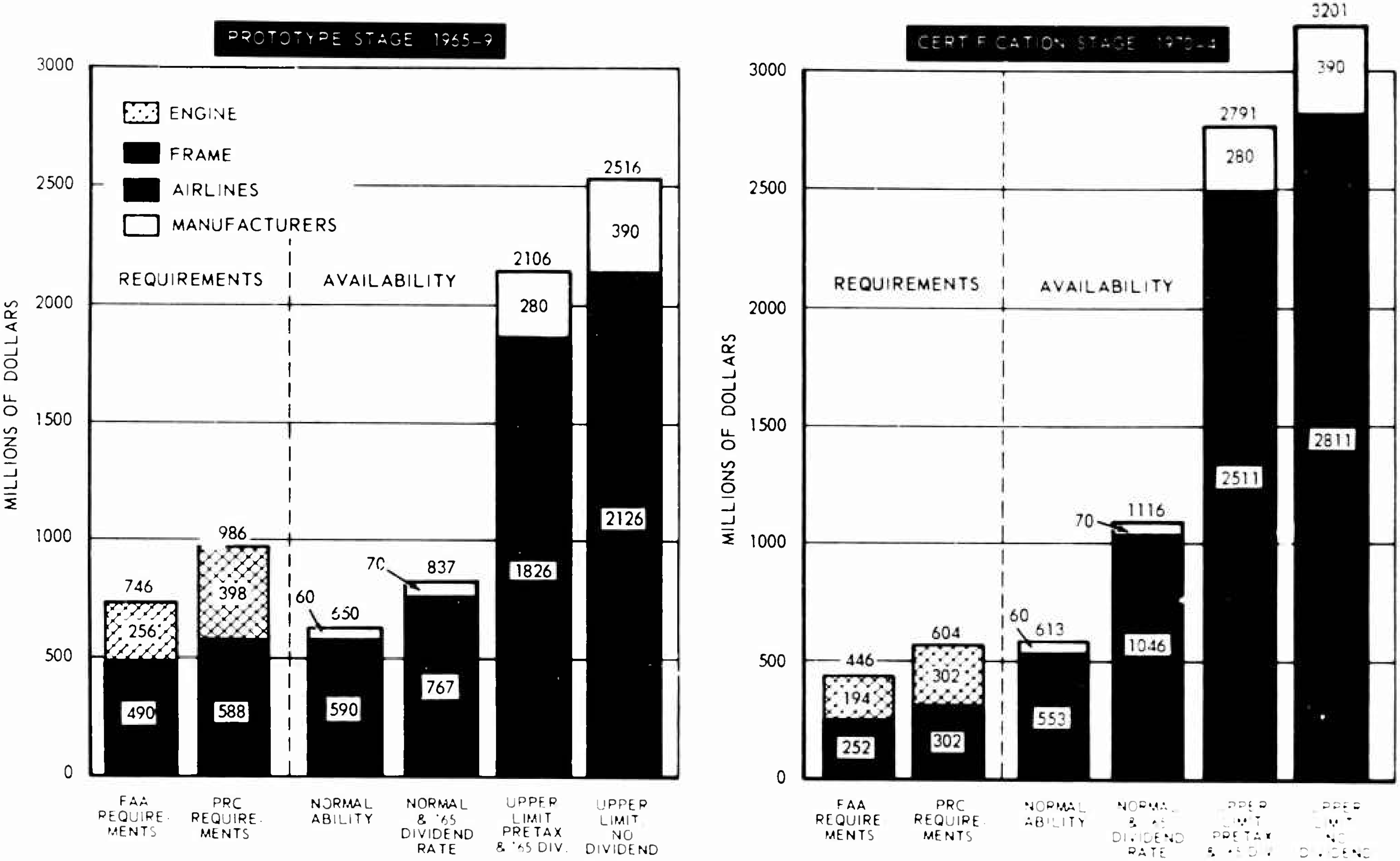

Figure 5.1. Projected SST requirements and financial ability (one producer).

million, $1,116 million, $2,791 million and $3,201 million, respectively.

The effect of the higher development costs estimated independently by Planning Research Corporation is to raise prototype requirements to $986 million, and certification requirements to $604 million.

Measured against program cash requirements, the ability of manufacturers alone is insufficient to finance the prototype and certification stages for any of the patterns of cash flow. The bulk of the ability rests with the airlines.

Once successful prototypes have been achieved, the airlines and manufacturers are expected to handle the subsequent production requirements by the historical combination of advance payments by airlines (possibly enlarged within acceptable limits), manufacturers' internally generated funds, and revolving bank credits. The cash requirements for production of the SST are expected to be approximately the same as would be required for an equivalent seat-mile capacity using only current and growth subsonic jets.

5.6 MANAGEMENT AND FINANCING OF THE SST PROGRAM

In view of the favorable operating economics of the Boeing 733-290, the prospects of a large aircraft market, and the apparent ability of the private sector to finance the major part of the development requirements, an alternative approach may now be possible to program financing and management. To date, the Federal Government has played the role of the managing entrepreneur in the SST Program. It now appears possible to consider reestablishing a more normal buyer-seller relationship between the airlines and manufacturers. The airlines and manufacturers would then jointly provide the major financial inputs, make the controlling decisions, and assume the major risks. The Government would assume the indirect catalytic role of making the SST Program sufficiently attractive to the airlines and manufacturers for them to undertake it as their own.

Once the airlines and manufacturers enter into this buyer-seller relationship, the alternatives of whether the pace of the SST Program should be more deliberate, and whether competition between manufacturers should be fostered become choices for them to make. Although such competition is apparently desired by both, it would be fostered only in the expectation of improvements in operating economics sufficient to outweigh the additional costs for development. The size of the ultimate market for two excellent designs may be such as to require two producers to satisfy aircraft demand on a timely basis.

Competition, however, must be a realistic alternative. The present problem is that there appears to be only one acceptable engine and airframe design. If the benefits of competitive SST prototypes, as against a monopoly producer, are desired, then a joint effort may be warranted by the Government, airlines, and manufacturers to secure effective competition.

5.7 COMPETITION AMONG AIRCRAFT

In the past, travelers, and hence airline managements, have generally preferred the faster aircraft whenever a choice was available. The faster aircraft was, in most cases, also the one with lower operating costs. This was the case in the piston-jet transition—a recent instance of displacement of one aircraft by a better one. In the

present case, the SST shows promise of lower costs per seat-mile than either the current or growth jets, but higher than the commercial CX-HLS. The Concorde shows higher costs per seat-mile than all other aircraft, but lower costs per aircraft-mile.

Considering now future possible worlds, there are three competitive situations—Concorde vs. SST, Concorde vs. commercial CX-HLS, and commercial CX-HLS vs. SST. If the Concorde were to prevail over the 154 principal SST-potential routes, then the expected result is a higher cost air transport system than that currently being operated. If either the SST or commercial CX-HLS prevail, however, the expected result is a lower cost system—particularly with the latter aircraft type.

The outcome of a competition between the Concorde and SST is quite clear. For comparable service and fares, the SST is expected to attract the traveler and displace the Concorde in all markets except those of low density.

The outcome of competition between the commercial CX-HLS and either supersonic aircraft is more difficult to predict. The total operating costs per passenger-mile of this large subsonic jet are significantly lower at any given load factor than those of the supersonic. However, at fare differentials no greater than 10 percent, the supersonic aircraft should operate at substantially higher load factors than the subsonic. Assuming no intervention by a Government or regulatory agency, the basic question to an airline management faced with unrestrained fare competition over a particular route is one of staying power—could the supersonic aircraft flying at 80 percent load factor, for example, match the costs of the commercial CX-HLS at a much lower load factor, say 35 percent?

For any situation supervised by regulatory authorities, it is unlikely, on the historical record, that such unrestrained competition would be permitted. On the international routes, reductions in fare levels are possible only with the implicit permission of the several governments involved. On the interstate domestic routes, such reductions require the approval of the Civil Aeronautics Board. The outcome of such subsonic-supersonic competition is expected to be one in which the two aircraft types coexist either on different routes—with each serving the markets for which it is best suited, or on the same route—with each attracting its own clientele.

5.8 BALANCE OF PAYMENTS EFFECTS

The impact of the SST Program on the U.S. balance of payments will depend on the extent to which:

a. supersonic aircraft may displace subsonic, and

b. the SST may be properly timed and more attractive than the Concorde.

If the long-range air transport market were to grow at the expected rate, there would be an aircraft requirement in 1980 for a seat-mile capacity equivalent to about 1900 current subsonic jets. This requirement could be met by various mixes of subsonic and supersonic aircraft in Free World fleets. A number of possible SST Program outcomes and corresponding fleet mixes were considered in determining the range of possible balance of payments effects. The resulting values of aircraft production and trade are listed in Table 5.4. The extremes as to program outcome (either the SST or the Concorde prevails) range between a positive balance on trade in aircraft of \$9.5 billions and a deficit balance of \$7.8 billions, respectively. The more probable outcomes if the SST Program were continued (with both subsonic and supersonic aircraft in the carrier fleets) would range between positive balances of

Table 5.4. Value of Aircraft Production and Trade (1965-1980) for Various Assumptions as to Program Outcome

Cases	Value of aircraft production (in billions $)						Value of trade in aircraft (in billions $)		
	Boeing 707-320B	Growth subsonic	Commercial CX-HLS	Boeing 733-290	Concorde	World total	U.S. exports	U.S. imports	Balance on aircraft
Pure SST	2.7	—	—	21.0	—	23.7	9.5	—	9.5
Pure Subsonic	7.2	6.6	4.6	—	1.7	20.1	7.4	1.0	6.4
Supersonic	2.7	—	—	14.6	10.6	27.9	6.9	6.4	0.5
SST-Subsonic	5.2	4.3	—	14.6	1.7	25.8	9.6	1.0	8.6
Concorde-Subsonic	6.4	4.3	—	—	20.2	30.9	4.3	12.1	-7.8

$0.5 to $8.6 billions. The case in which the subsonic aircraft prevail would show a positive balance on trade in aircraft of $6.4 billions.

Regardless of the choices made among U.S. program alternatives, the balance of payments impact will be distributed over at least 20 years (approximately 1970 to 1990), with perhaps 60 percent occurring in the first decade. Moreover, to the extent that the export aircraft are financed in the United States, the effects on balance of payments will be further diffused over time. The impact on the overall U.S. balance of trade could be lessened by compensatory effects in other product areas in which we trade. Thus, a substantial success for the SST Program could increase U.S. national income, which might then lead to increased U.S. imports of a variety of foreign-made products. Conversely, a substantial success for the Concorde could have analogous compensatory effects which would tend to diminish its impact on U.S. balance of payments.

6. STUDY APPROACH

The success of any program for improving long-range air transport is determined by a large number of factors interacting in a complex manner. Recognizing this complexity, the approach taken here involved the following steps:

a. definition of the aircraft alternatives,

b. definition of the criteria by which the aircraft would be ranked as to their relative economic merit,

c. sketching a number of possible program outcomes (or alternative futures) which might result under explicitly stated conditions,

d. examination of alternative programs and of the sensitivity of the choice among them to variations in estimates of the critical factors.

In summary, the study approach has been designed to provide a substantial body of information immediately useful to the SST Advisory Committee, as well as the analytic machinery for quickly exploring additional questions likely to arise. Wherever possible, parallel sources of data and methods of analysis were used to check the results derived and to gain additional insight. However, it was recognized from the outset that, even when all of the factors have been analyzed as carefully as the limitations of time and data permit, there would still remain large areas in which the policymakers must weigh the intangibles and uncertainties. In this spirit, the analysis has been designed to illuminate the range of choice before the policymakers, thus facilitating the use of judgment for those factors which are truly incapable (with the present state of knowledge, at least) of being analyzed.

6.1 SCOPE OF STUDY

The present study is quite similar in concept to that which a businessman would perform in analyzing alternative ventures. He would identify some specific need in the market, examine the alternative means for supplying that need, and determine his costs. He would then rank his alternatives, weigh any intangibles, and decide which of the ventures he would undertake. Referring to Figure 6.1, the same factors—need in market, means of supply, costs—are seen to enter the SST Economic Analysis. However, because of the enormous technical and commercial risks in the SST Program, the scope of the analysis has been broadened to provide an estimate of the aircraft market, a ranking of the program alternatives, and estimates of the economic significance of boom, of the impact of risk-sharing on the manufacturing and air transport industries, and of the impact on U.S. balance of payments. The other system costs attending the introduction of the SST have been only briefly examined, and found to require far more study than was possible within the available time.

Figures 6.2 and 6.3 illustrate the nature of the analysis. The first figure, defining the economic activity being studied, has the following significance:

a. The U.S. domestic manufacturers design and produce aircraft which are sold to the Free World

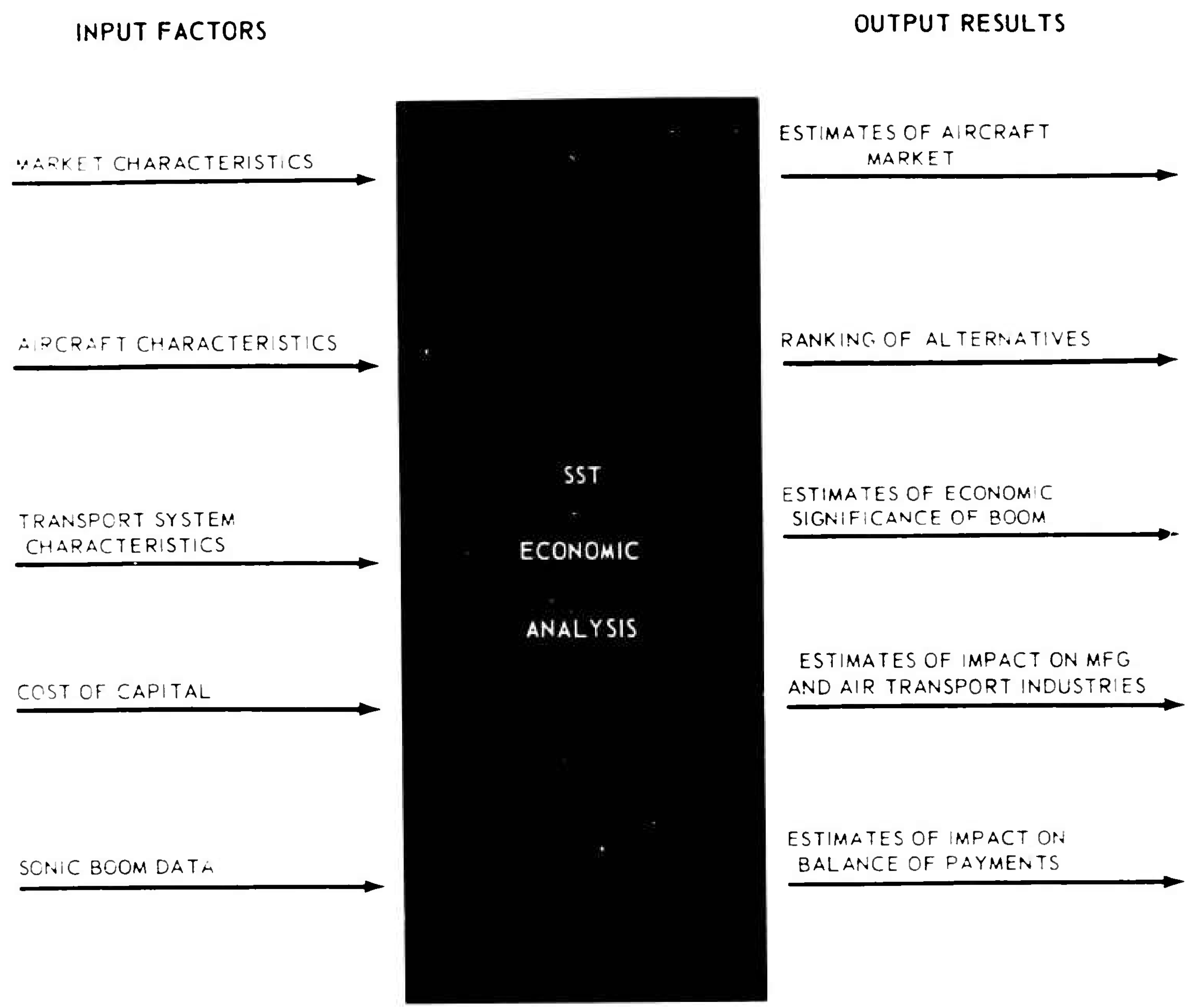

Figure 6.1. Inputs and outputs of SST economic analysis.

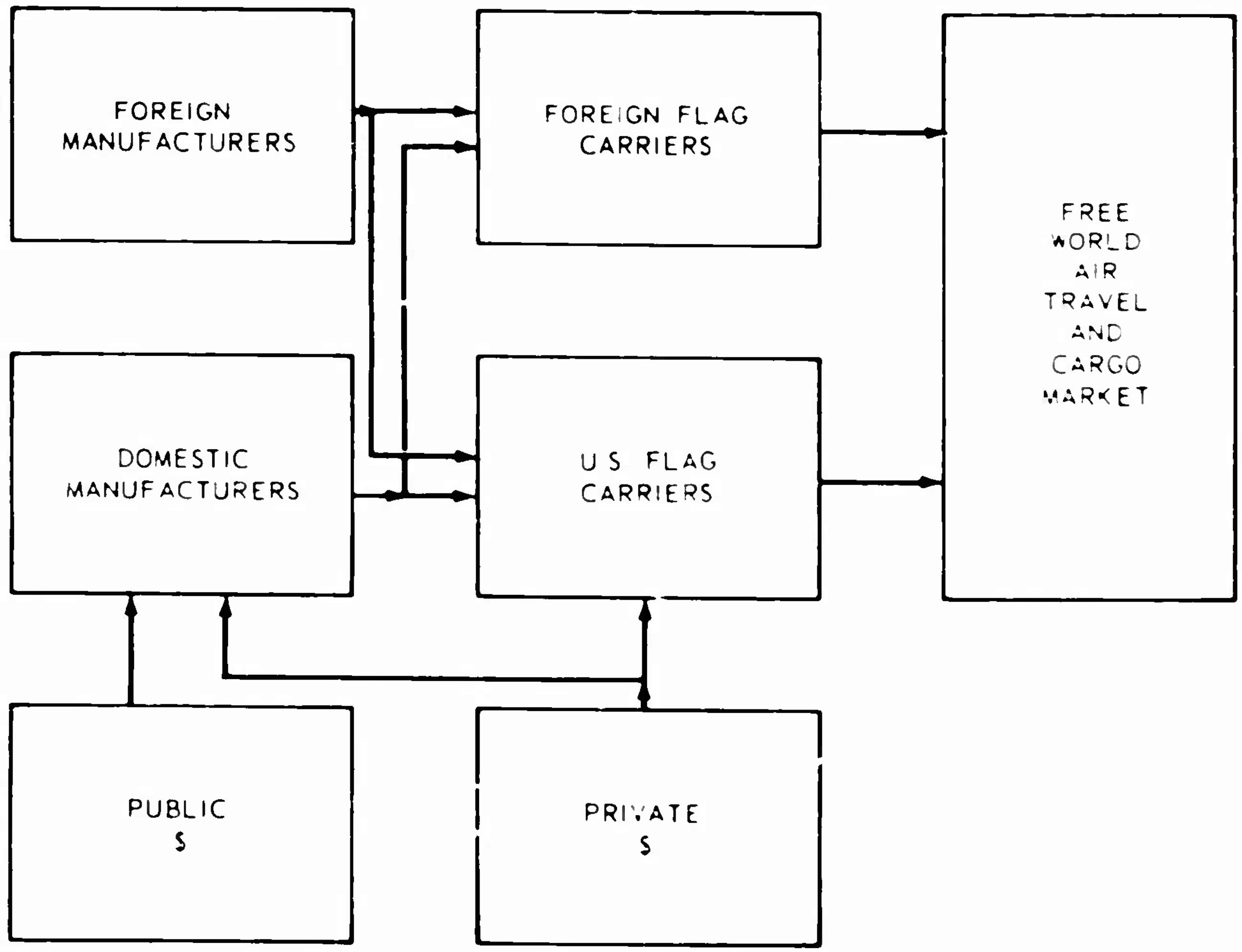

Figure 6-2 Definition of economic activity being studied

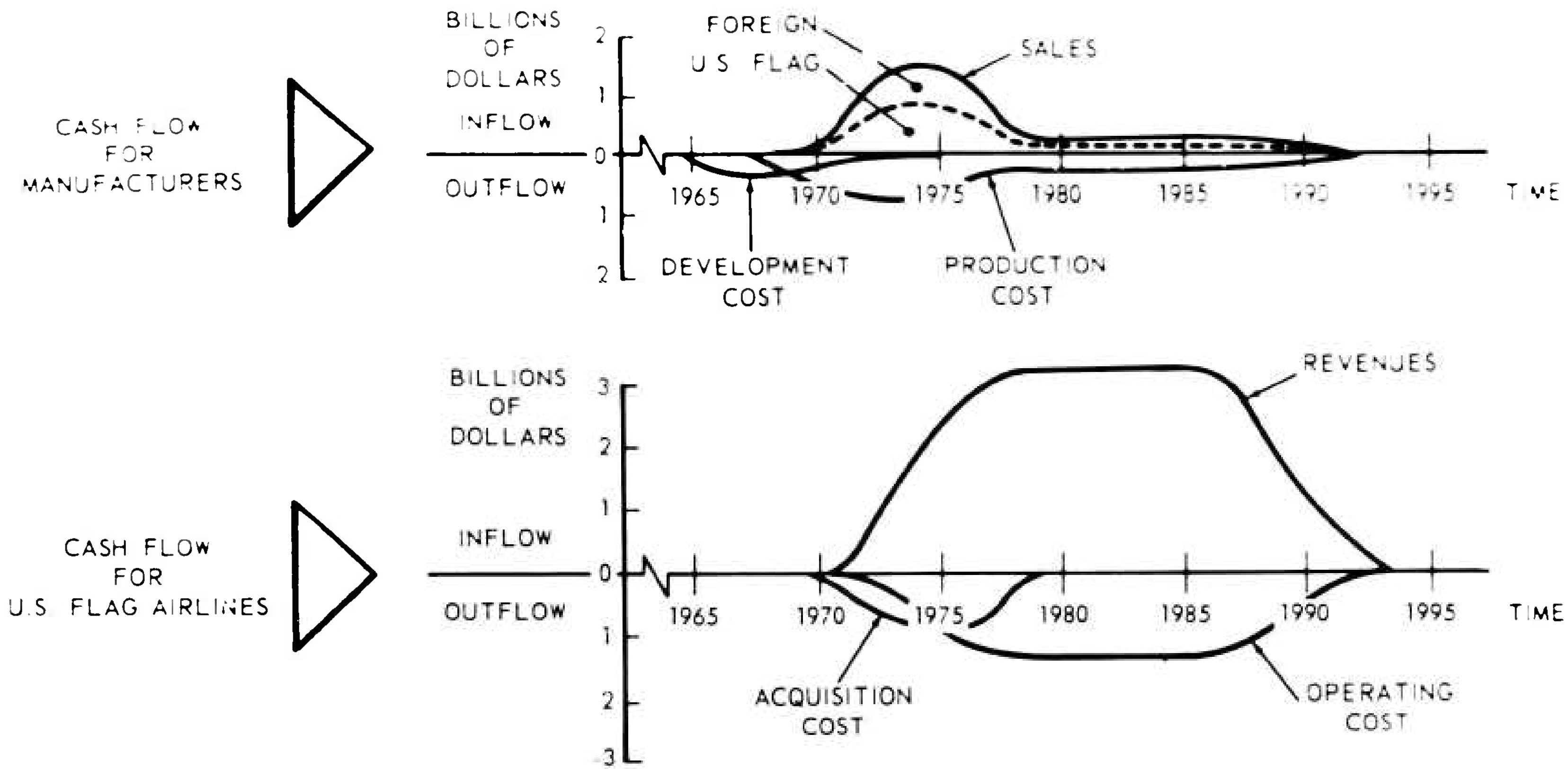

Figure 6.3. Typical cash flows over life cycle of SST Program (quantity 200).

carriers. The American product competes with the Concorde.

b. The Free World carriers provide transport services to the air travel and cargo market.

c. Capital may be provided from public and private sources to assist in the financing of the Supersonic Transport Program.

In observing the economic activity under study, one would first see cash flowing in to initiate the SST Program; later, aircraft and parts flowing to the carriers, and transport services to the users, with cash flowing back to compensate; and finally, cash flowing out to repay the lenders and investors. The nature and magnitude of the cash streams would vary depending on many factors such as the rate of growth of air transport, the restriction of operations due to sonic boom, and the cost and performance of the SST relative to competing aircraft.

Figure 6.3 presents typical patterns of cash flows over the life cycle of the SST Program. These cash flows are shown separately by sector for the manufacturers and the U.S. Flag carriers. Costs incurred by any sector are shown as outflows; revenues, as inflows. The cash flows for the manufacturers and the airlines may be added together to produce a net cash flow over the program life cycle. Given the uncertainties in estimating future cash flows, this study has been purposely designed to facilitate the examination of many alternative future situations (i.e., various combinations of costs, markets, boom restrictions, etc.) quickly, cheaply, and under carefully specified test conditions.

Figure 6.4 shows the several tasks into which the overall economic analysis was structured. The basic purpose of these tasks was to provide the information base from which cash flows under specified conditions could be generated, as well as the tools for analyzing and interpreting their significance to the SST Program decision. These several tasks are as follows:

a. Demand for air transport in the Free World over the time period 1965-1990.

b. Computer simulation of the Free World route system over which the supersonic transport and the competing aircraft may fly.

c. Economic effects resulting from boom damage claims, as well as from restrictions on, or modifications of, airline operations because of sonic boom.

d. Relationships between the performance of aircraft (both subsonic and supersonic) and the associated costs of development, production and operations.

These tasks provided the basic input data which were then combined to yield:

e. Cost-benefit analysis of the alternative programs for improving long-range air transport.

f. Ability of the manufacturing and air transport industries to share the risks associated with the SST Program.

g. Effects on the U.S. balance of payments.

The analyses relating to these several tasks were then integrated to provide the desired output information.

6.2 TREATMENT OF UNCERTAINTY

A high degree of uncertainty exists in many areas, as follows:

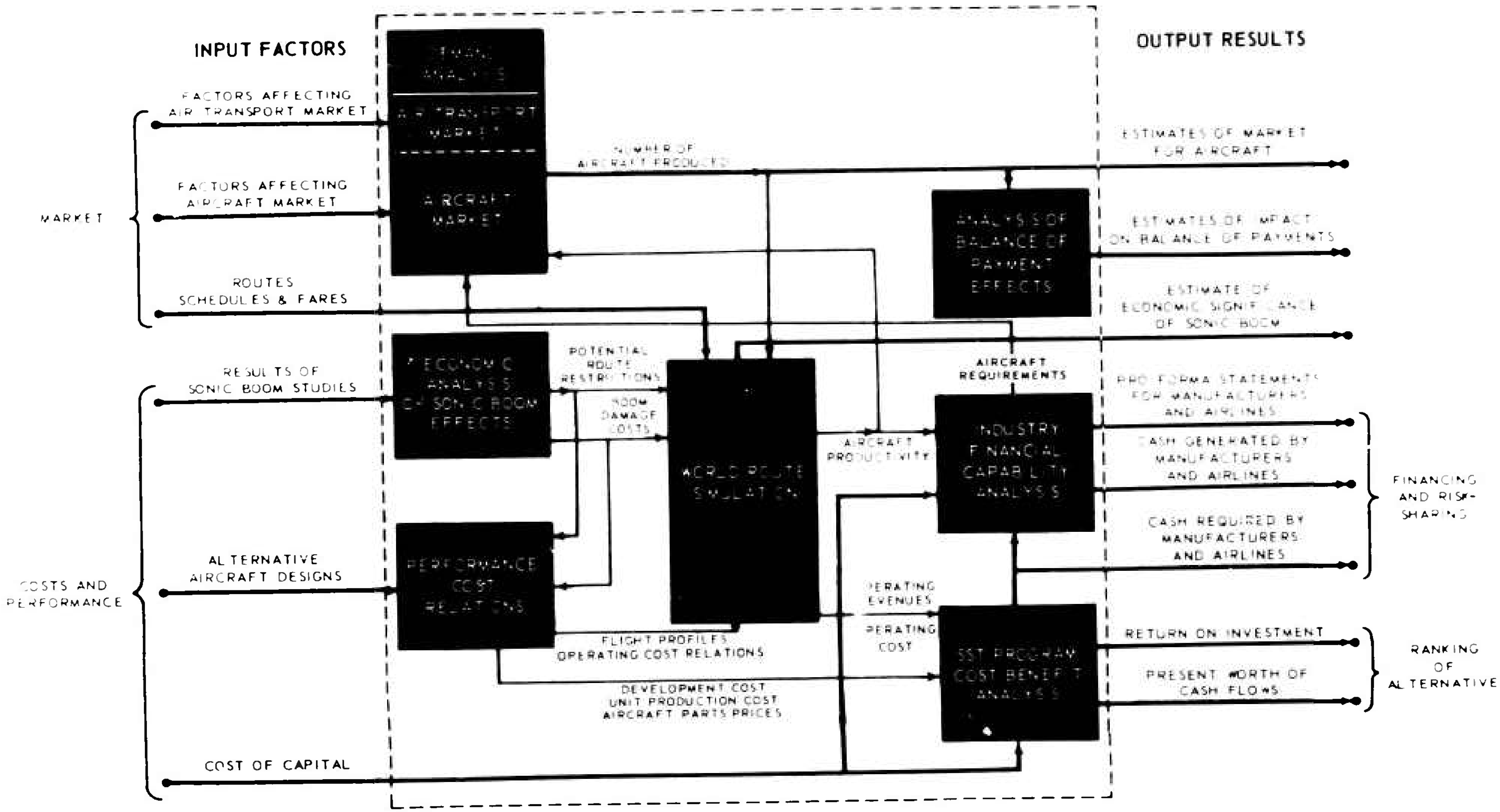

Figure 6.1. Approach to SST economic analysis.

a. the magnitude of the costs and the time interval for achieving a given level of aircraft performance,

b. the performance of competing aircraft and the timing of their entry into the market,

c. the nature and scope of the future demand for air transport,

d. the socio-political reaction to sonic boom,

e. the ability and willingness of the private sector to share in the risks of the SST Program,

f. the future actions of governments in allocating routes, setting fares, subsidizing operations, and entering into agreements on air transport.

With uncertainty an intangible affecting every aspect of the SST Program decision, the various estimates here presented should be regarded as expected results, lying within a probable range of variation. Our approach is one of indicating explicitly the areas in which uncertainty is known to exist, and offering, wherever possible, quantitative estimates of the ranges within which results may fall.

With regard to the costs of the various advanced aircraft considered here, a measure of the uncertainty is indicated by the range of estimates which have been made by four expert technical groups: the manufacturers, the FAA evaluation team, and our own contractors (Planning Research Corporation and Operations Research, Incorporated). These estimates of development, production and operation costs are given in Section A1, and enter directly into the analysis of the sensitivity to errors in estimation (Section A3). In addition, separate estimates of the range of errors in the more important performance and environmental parameters (e.g., lift/drag ratio, specific fuel consumption, and temperature) will be examined in subsequent analyses to determine their potential effects on airlines costs and revenues.

Estimates as to the expected growth in demand of Free World air transport were prepared by a contractor (Systems Analysis and Research Corporation) and by the SST economic study staff. The methodology and results were critically reviewed with the CAB, with several airlines, and with the manufacturers. These estimates then entered into two independent approaches to determining the probable requirement for aircraft (Section A2) and impact on balance of payments (Section A6).

With regard to sonic boom, the analyses of our contractor (Institute for Defense Analyses) have persuaded us that the primary problem here is socio-political rather than physical. Recognizing the impossibility of accurately predicting socio-political reactions, our analyses have been concerned with the two extremes (negligible reaction to boom, and a reaction so severe as to restrict SST operations to the overwater routes) and with three intermediate situations. Incremental costs of providing SST service to varying numbers of U.S. domestic city-pairs were computed so as to provide a range of estimates (Section A4) for situations in which the SST is operated over densely populated areas.

While the ability of the private sector to share in the risks of the SST Program may be approximately determined, its willingness to share is a major imponderable. This willingness depends very heavily on the plan developed for managing and financing the SST Program, and conversely, the plan depends on the willingness. It is reasonably clear from our extensive discussions with airlines and manufacturing executives, however, that their willingness would increase to the extent that the controlling decisions were left in private hands (Section A5).

The future actions of governments are a second major imponderable affecting the program choices. Operating on a global scale, the airlines require the consent (and indeed, the concerted action) of the governments of the many nations being served by the air transport system. Each of the strategies open to us may require a different degree of concerted action, and hence, may differ in its political feasibility. Clearly, the prediction of such concerted action a decade hence requires political judgment of a high order—particularly when France and Britain (and possibly, Russia) are presently following competitive strategies with respect to the development of advanced aircraft.

6.3 LIMITATIONS OF STUDY

One limitation stems from the fact that the various aircraft necessarily received differing quality of treatment. Since the manufacturers and airlines have devoted far more thought to the SST than to the commercial CX-HLS, the data available for each aircraft vary both in quantity and quality. Much data of reasonably good quality are now available on the SST as a passenger transport; relatively little on the CX-HLS (either as a passenger transport or as a mixed passenger-cargo transport). In like manner, the design data for the Concorde are not entirely comparable to those of the SST designs. However, these data have been reviewed by NASA and do represent the best information available, erring possibly in favor of the Concorde.

A second limitation relates to the time and effort that was available for the analysis of the system costs (both investment and operating) that would attend the introduction of the SST and the CX-HLS. Both aircraft are several times as productive in generating seat-miles as the Boeing 707-320B. However, the SST provides this increased productivity by increased seating capacity and speed; the CX-HLS, by greatly increased seating capacity. The large differences in speed, seating, and flight frequencies have important implications for the air traffic control system and for air terminal facilities. Moreover, the SST cruises at a higher altitude than the CX-HLS, so that there are significant differences in the requirements for world-wide meteorological data. Finally, the proportions of total airways costs allocable to the SST or CX-HLS (as compared with other aircraft using the same facilities) can only be determined by extensive and detailed analysis. Such an analysis was felt to lie outside the scope of the present study.

6.4 IMPLEMENTATION OF STUDY

Mr. Abraham Katz, Special Assistant to the Secretary, was responsible for the performance of the SST Economic Analysis. Staff personnel were drawn from the several interested agencies as follows:

Treasury Department	Daniel J. Edwards
Department of Defense	Robert E. Pursley (Lt. Col.)
Department of Commerce	B. Paul Blaine, Jr. Albert M. Dodds Robert A. Fish Richard Hellman Matthew R. Monahan Paul E. Shea George F. Wirth
Civil Aeronautics Board	Samuel L. Brown Frank M. Lewis Herbert C. Hautau
Federal Aviation Agency	George Baughman

National Aeronautics & Space Administration — John G. Lowry, John T. McShera, Jr.

The project manager secured the advice of the designated representatives of the members of the SST Advisory Committee.

The several tasks concerned with the preparation of input information were largely performed under contract by the following firms:

- Aviation Advisory Service
- Booz, Allen, and Hamilton, Inc.
- Institute for Defense Analyses
- International Business Machines Incorporated
- Operations Research, Incorporated
- Planning Research Corporation
- Systems Analysis and Research Corporation

In each of these input areas, substantial work was done by the SST study staff to direct and supplement the work of the contractors. The tasks concerned with the preparation of output results were performed entirely by the SST staff. Criticism and guidance were provided by consultants outstanding in the fields of airline operations, finance, transportation economics, and general economics.

The performance of the study was greatly facilitated by the cooperation and support provided by the following organizations:

Manufacturers

- The Boeing Company
- Douglas Aircraft Company, Inc.
- General Electric Company
- Lockheed Aircraft Corporation
- North American Aviation, Inc.
- United Aircraft Corporation

Airlines

- American Airlines
- Eastern Air Lines, Inc.
- National Airlines
- Northwest Airlines, Inc.
- Pan American World Airways
- Trans World Airlines
- United Air Lines

Trade Associations and Unions

- Air Transport Association
- Airport Operators Council
- Air Line Pilots Association

A number of financial and casualty insurance firms also contributed valuable information to this study. Working relationships with these several organizations have been amicable and productive.

SUPPORTING INFORMATION

A1. AIRCRAFT DESCRIPTIONS

A1. AIRCRAFT DESCRIPTIONS

The purpose of this section is to present the characteristics, performance and costs of the six aircraft types considered in this study. The subsonic types are the current large jet (Boeing 707-320B), a growth version of the current jet, and a commercial CX-HLS (Cargo Experimental — Heavy Logistics Support). The supersonic types are the Boeing 733-290, the Lockheed L2000-2P, and the Anglo-French Concorde. In Table A1.1 are listed the sources of data for the various aircraft; in Table A1.2, the more important characteristics and performance data. Figure A1.1 shows a typical mission profile with the speeds and altitudes of operation. Each of the aircraft will be described briefly below.

A1.1 SUMMARY DESCRIPTIONS

Current Subsonic Jet

The Boeing 707-320B is a recent model of a series of aircraft that began with the Boeing prototype 707-80. The first commercial transport of this series, the 707-120, went into service in October 1958; the 707-320B, in June 1962.

This aircraft is used here for comparison purposes, since its engine and airframe technology represent current state-of-the-art, and it is one of the more efficient long-range aircraft. Current aircraft sales price is used; performance data are based on actual flight information.

Table A1.1. Aircraft Considered and Sources of Data

Aircraft	Data sources
Large Subsonic Jets	
Current model Boeing 707-320B	Manufacturers and airlines
Growth model Boeing 707-820 Douglas DC-8-61	Manufacturers
Commercialized logistics aircraft Boeing CX-HLS Douglas CX-HLS Lockheed CX-HLS	Manufacturers
Large Supersonic Jets	
Boeing 733-290	Manufacturers and FAA
L2000-2P	Manufacturers and FAA
Concorde	Manufacturers' brochures, and NASA

Table A1.2. Aircraft Characteristics and Performance

	707-320B[1]	Growth subsonic[2]	CX-HLS[2]	733-290[3]	L2000-2P[3]	Concorde[2]
<u>SPEED</u>						
Cruise Mach number	0.82	0.82	0.82	2.7	3.0	2.2
<u>WEIGHTS</u>						
Maximum ramp weight, lbs.	328,000	370,000	686,900	500,000	458,000	328,130
Maximum takeoff gross weight, lbs.	326,000	368,000	682,400	496,500	455,350	326,000
International operating weight empty, lbs.	140,000	162,000	357,000	224,940	203,000	142,000
<u>ENGINE</u>						
Takeoff thrust per engine, lbs.	18,000	21,000	39,000	36,690	50,500	35,000
Dry engine weight, lbs. engine	4,200	4,570	6,470	8,545	10,355	5,600
<u>CAPACITY</u>						
Cargo and baggage volume, cu. ft.	1,668	2,900	3,834	1,508	1,370	618
Maximum payload, lbs.	44,000	69,000	146,718	48,600	45,000	26,000
Total number of seats (10-90 split)	161	215	652	228	210	108
(20-80 split)	149	207	579	209	194	101
<u>DESIGN PERFORMANCE</u>						
Range at maximum payload, st. mi.	5,340	4,188	3,020	3,800	2,300	3,900
Sonic boom (acceleration/cruise) psf	--	--	--	2.5/1.7	2.5/1.7	2.0/1.5
Block time @ 4000 st. mi., hrs.	7.9	7.9	7.72	2.96	2.78	3.60
Block fuel @ 4000 st. mi., lbs.	92,000	100,000	179,000	198,100	221,000 @ 3,500 (st. mi.)	139,000
Reserve fuel @ 4000 st. mi., lbs.	16,800	20,450	37,000	37,000	31,500	27,000

[1]Manufacturers' flight manuals.
[2]Manufacturers' estimate
[3]FAA validated.

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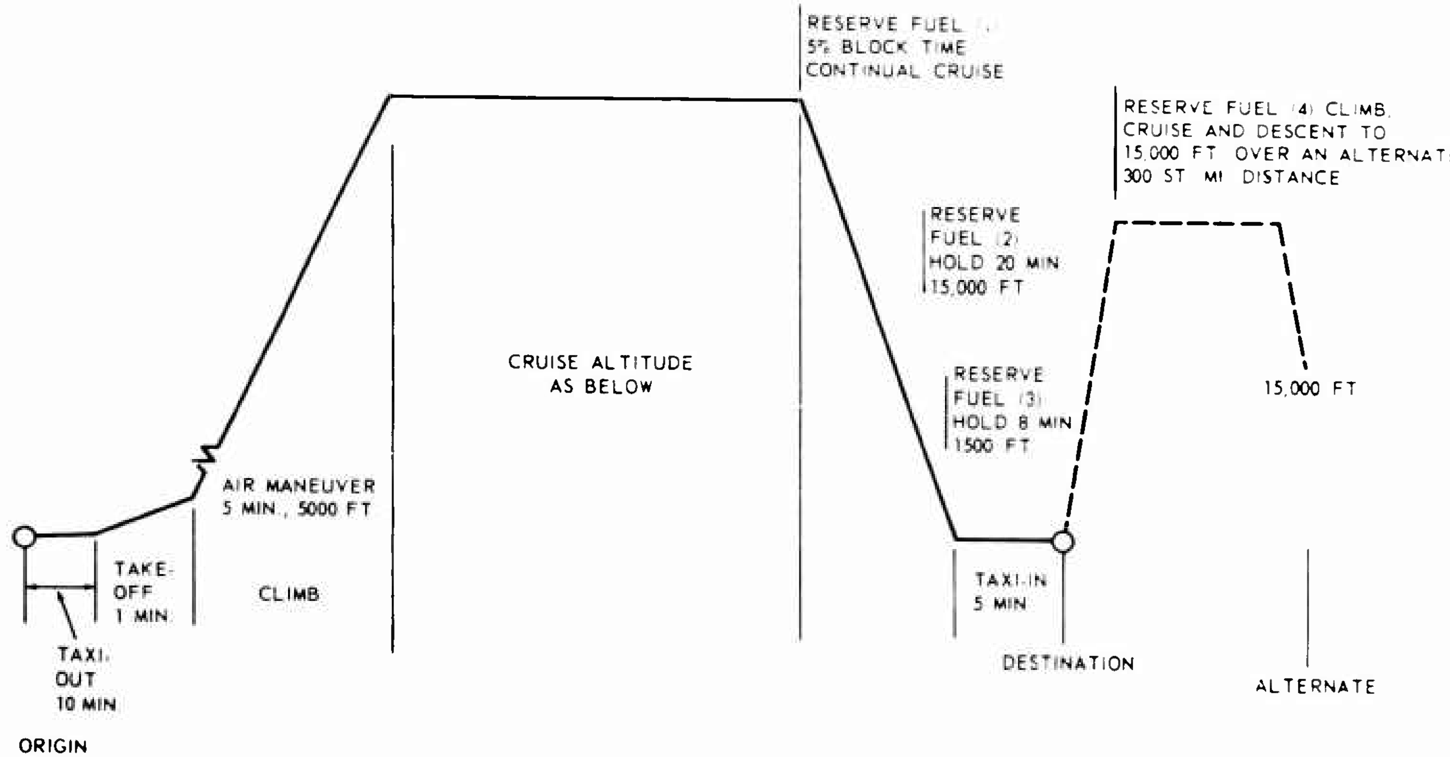

Figure A1.1. Typical mission profile.

Aircraft	Cruise altitude (feet)	Cruise procedure	Cruise Mach number	Temperature and wind conditions
707-320B	35,000	Constant altitude	0.82	Standard-day, no wind
Growth subsonic	35,000	Constant altitude	0.82	Standard-day, no wind
Commercialized CX-HLS	Average altitude 35,000	Climb in cruise	0.82	Standard-day, no wind
733-290	65,000 to 75,000	Climb in cruise	2.7	Standard-day, no wind
L2000-2P	65,000 to 75,000	Climb in cruise	3.0	Standard-day, no wind
Concorde	55,000 to 65,000	Climb in cruise[1]	2.2	Standard-day, no wind

[1]Unless modified by boom restrictions.

[redacted]

Growth Version of the Current Subsonic Jet

This aircraft represents the next evolutionary step, utilizing current experience and technology. Numerous growth versions of current aircraft are possible, some optimized for transcontinental distances and some for intercontinental distances. Aircraft deliveries could begin in 1967. The manufacturers' suggested sales price an per-formance characteristics are used.

The major changes to the current jet will be fuselage extensions (about 400 inches) to increase the passenger-carrying capability from 161 to at least 215 in a mixed first class economy configuration. The transcontinental versions will be able to use existing engines, thus avoiding increases in the engine sales price and parts inventory. The intercontinental versions will require more powerful engines. Evolutionary aerodynamic improvements permit the larger payloads over the longer ranges. (Information made available after these data were processed indicates the possibility of even larger payloads and slightly higher cruise speeds.)

Commercialized CX-HLS

A commercial version of the CX-HLS military transport represents an advanced aircraft which could be made available in 5 to 7 years. The commercial CX-HLS might accommodate as many as 700 passengers (all economy). Its cargo and baggage volume would be 3834 cubic feet compared with 1668 cubic feet for the 707-320B. Aircraft performance and cost data were obtained from Boeing, Douglas, and Lockheed.

No major improvements in airframe technology would be required for the CX-HLS. The engine, however, would represent a difficult development task. It would be a large turbofan, producing 38,600 pounds of thrust as compared with 18,000 pounds for the current 707-320B engine. The CX-HLS is a high-wing aircraft in contrast to the conventional low-wing commercial configurations.

Boeing 733-290

Boeing proposed a basic SST design in two versions, an international (733-290) and a domestic (733-291). The 733-290, used in this study, has a gross weight of 500,000 pounds (a 70,000-pound increase over the January 1964 design). The Boeing aircraft can carry its full 48,600 pound payload to 3800 statute miles with 2.5/1.7 psf overpressures (228 passengers in a mixed first class economy configuration). At 4000 statute miles and the same overpressures, the payload capability is 43,000 pounds (215 passengers). At 4000 statute miles and 2.0/1.5 psf overpressures, the payload falls to 25,500 pounds.

The domestic version, 733-291, has a gross weight of 425,000 pounds, and is identical to the 733-290 in body length, diameter, engines, and planform. The structure is lightened for the lower operating weight. The payload capability (209 passengers in a mixed first class/tourist configuration at domestic ranges) is relatively unaffected by 2.0/1.5 psf overpressure restrictions.

The 733-290 and 733-291 are designed to cruise at Mach 2.7. The wing sweep in both versions can be varied from 20 degrees for takeoff and landing to 72 degrees for supersonic cruise. Intermediate sweep angles are used to optimize other speed regimes. The primary structural material is titanium. Conventional forming methods are to be used in assembling primary structures. The aircraft is powered by 4 General Electric afterburning turbojet engines, the engine preferred by Boeing. Each engine is capable of 36,690 pounds of thrust at sea-level static conditions. Both

aircraft versions can also utilize the Pratt & Whitney engine.

Lockheed L2000-2P

Lockheed proposed a basic SST design in three versions: a small international (L2000-1P), a large international (L2000-2P), and a domestic (L2000-3P). Each aircraft, however, has the same gross weight of 458,000 pounds and the same wing and engine configuration.

The aircraft used in this study is the L2000-2P, indicated by Lockheed to have the greatest potential. It has (according to the manufacturer) a design payload capability of 45,000 pounds (210 seats in a mixed configuration) at a range of 3400 statute miles with 2.0/1.5 psf overpressures. Lockheed further indicates a 33,190 pound payload for 4000 statute miles and 2.0/1.5 psf overpressures. However, the FAA Phase IIA evaluation concluded that the maximum range for the L2000-2P, with zero payload and overpressures relaxed to 2.5/1.7 psf, would be 3250 statute miles. Aerodynamic deficiencies were cited as the cause for this payload/range reduction. Because of these deficiencies, the Lockheed design was not treated as exhaustively here as the Boeing design.

The L2000-1P has a smaller fuselage, with a passenger capacity (all economy) of 170. The L2000-3P has a longer fuselage, with a capacity of 250.

The Lockheed designs have a "double delta" wing and a cruise speed of Mach 3.0. The airframe structure is conventional, with titanium alloy the primary structural material. Conventional joining methods are employed. The aircraft is powered by 4 Pratt & Whitney STF 219-L duct-burning, turbofan engines, the engine preferred by Lockheed. Each engine is capable of approximately 50,500 pounds of thrust at sea-level static conditions. All designs can use the General Electric engine.

Concorde

An aircraft believed to be representative of the Concorde was also included in this study. The aircraft has a slender ogee wing, and is designed to cruise at Mach 2.2, a speed which permits using conventional aluminum alloys. Its Olympus 593 engine represents a compromise between high thrust and low fuel consumption. It should be noted that the Concorde was designed to less stringent takeoff and landing specifications than the SST designs.

The available performance and characteristics data are limited. Even the airlines have relatively little aerodynamic, propulsion, and structural information. Our data were obtained from company brochures, and reviewed by NASA. The performance calculations were made, however, in a manner consistent with that used during the SST evaluation in January 1964. Where performance was uncertain, the Concorde was given the benefit of the doubt.

A1.2 DEVELOPMENT AND PRODUCTION COSTS

It is widely recognized that there is a high degree of uncertainty associated with estimating the costs—development, production, and operating—for any advanced aircraft. Accordingly, a number of estimates are here presented. The sources of estimates include the manufacturers, the Federal Aviation Agency's Phase IIA Evaluation Team, and our own cost-performance contractors, (Planning Research Corporation, PRC, and Operations Research, Incorporated, ORI). The methodologies underlying our contractors' cost estimating relations are discussed in detail in Parts II and III.

[redacted]

Estimates of the production and development costs for the various aircraft are presented in Tables A1.3 and A1.4. Except for the current subsonic jet and its growth version, there are several estimates of production costs given for each aircraft, as well as several estimates of development costs for the Boeing and Lockheed SST designs. The incremental costs given by the manufacturer for development of a commercial CX-HLS are relatively small (about $70 millions), and hence are not shown.

Differences in costs, as estimated by the various expert groups, should be expected because of differences in approach used. Without going into the details, the following basic differences in the estimating procedures exist:

a. The manufacturers estimated cost on an item-by-item basis, using their own past experience as a guide.

b. The FAA reviewed the manufacturers' estimates in detail, applying engineering judgment and using analysis of historical data on related programs.

c. The ORI and PRC estimating relationships were based on general aircraft characteristics, with the equations being derived through statistical regressions of historical data and use of engineering judgment.

d. The samples of historical data used by each group varied because of relative availability of data and the criteria used to determine relevance to the SST designs.

e. The choice of variables used for estimating purposes varied (e.g., ORI based their estimates of engine development cost on thrust, speed, and turbine inlet temperature; PRC, on thrust and speed).

A1.3 OPERATING COSTS

Three sets of operating cost equations are used in this study:

a. FAA uses a modified version of the Air Transport Association formulae for estimating direct operating costs, and a method developed by Boeing and Lockheed to estimate the indirect costs.

b. PRC equations are similar to those of the FAA, but differ in the handling of certain items such as crew costs and food costs.

c. ORI equations use different variables for estimating indirect costs. For example, FAA and PRC relate costs to passengers and aircraft departures; ORI, to passenger revenues and "weighted" aircraft departures.

A detailed discussion of these equations is presented in Parts II and III. A comparison of the direct and indirect costs per seat-mile as estimated by the three methods are shown in Figure A1.2 for the Boeing 733-290, commercial CX-HLS, and Concorde. For each curve of operating cost, there are two kinds of input information: aerodynamic data and aircraft sales price data. The aerodynamic inputs (e.g., fuel burned, block time, payload range) are as validated by FAA for the 733-290, and as given by the respective manufacturers for the other two. The sales price inputs are those estimated by the manufacturers, FAA, PRC, and ORI, respectively. The FAA and manufacturers' curves are then derived by using the FAA operating cost estimating relations (CER); the PRC and ORI estimates, by using the respective set of cost relations. The major source of variance in these several estimates is in the indirect operating costs, with ORI being significantly higher than the others.

[redacted]

[redacted]

Table A1.3. Summary Comparison of Unit Costs for Aircraft Considered[1]
Cost in millions—1963/64 dollars

	707-320B	Growth Versions	Commercial and CX-HLS			Concorde			Boeing 733-290				Lockheed L2000-2P			
	Mfg.[2]	Mfg.[3]	Mfg.[4]	PRC[5]	ORI[5]	Mfg.[6]	PRC[7]	ORI[7]	Mfg.[8]	FAA[8]	PRC[9]	ORI[9]	Mfg.	FAA	PRC[9]	ORI[9]
Production Cost																
Airframe and avionics	$5.93	$8.26	$14.0	$19.3	$17.4	$10.7	$13.7	$ 9.2	$17.2[10]	$19.3	$25.1	$25.4	$18.7	$20.9	$22.9	$26.4
Engines	1.03	1.24	2.0	4.8	3.2	2.8	4.5	3.9	3.9[11]	4.1[11]	4.4[12]	4.6[12]	8.0[12]	5.8[12]	7.4[12]	6.0[12]
Sub-Total	$6.96	$9.50	$16.0	$24.1	$20.6	$13.5	$18.2	$13.1	$21.1	$23.4	$29.5	$30.0	$26.7	$26.7	$30.3	$32.4
Development Cost-Prorated																
Airframe and avionics									$ 3.4	$ 3.7	$ 4.5	$ 5.3	$ 3.9	$ 4.4	$ 4.3	$ 5.2
Engines									1.9	2.3	3.5	1.8	4.9	2.3	5.1	2.6
Sub-Total									$ 5.3	$ 6.0	$ 8.0	$ 7.1	$ 8.8[13]	$ 6.7	$ 9.4	$ 7.8
Total Production plus Development Cost	$6.96	$9.50	$16.0	$24.1	$20.6	$13.5	$18.2	$13.1	$26.4	$29.4	$37.5	$37.1	$35.5	$33.4	$39.7	$40.2

[1]Excluding spares, ground equipment, and facilities outlays.

[2]Current market selling price.

[3]The use of this manufacturer's estimate should introduce only small errors since the aircraft is a near-term extrapolation of current art.

[4]Manufacturer's estimate with a military version in production.

[5]PRC and ORI cost estimating formulae, based upon preliminary configuration data, estimate unit costs for 200 aircraft excluding development costs. However, no allowance is made for learning that would be obtained from a preceding military program.

[6]The price shown is based on information available from the manufacturers and airlines. The price is believed to be based on 100 aircraft, but it is not known if development costs are included.

[7]Estimates are for an American version of an aircraft with Concorde characteristics. Values are unit costs at 200 aircraft.

[8]Includes Boeing's "proposed contingency" amount.

[9]PRC and ORI estimates are based upon the cost equations presented in their reports in Part III. These numbers will differ somewhat from those presented in their reports due to various revisions to conform to later developments.

[10]Boeing's estimate includes approximately $0.8 million per aircraft for profit and contingencies percentages taken on the engine. None of the other airframe estimates include explicit charges based upon the cost of the engines.

[11]General Electric includes one-half of the estimated post-certification development costs in its engine unit price; the remainder (approximately $162 million) General Electric proposes to charge against spare parts sales.

[12]Engine cost includes Post-Certification Development.

[13]Lockheed's estimate includes $56 million (about $0.3 million per aircraft) for profit. Profit is not included in any of the other development cost estimates. (Profit is included in the production cost estimates. Ten percent is used as the profit rate for all production cost estimates except for General Electric's engine estimates which are based upon fifteen percent.)

[redacted]

[redacted]

Table A1.4. Summary Comparison of Supersonic Transport Cost Estimates (Total Cost for 200 Aircraft)
Cost in millions—1963 64 dollars

	Boeing 733-290 GE4-J5G Engine				Lockheed L2000-2P P&W STF-219L			
	Mfg. estimate	FAA[1] estimate	PRC[2] estimate	ORI[2] estimate	Mfg. estimate	FAA estimate	PRC[2] estimate	ORI[2] estimate
Production Cost—200 Aircraft								
Airframe and avionics	3444[3]	3560/3870	5020	5070	3739	4182	4574	5280
Engines—including post-cert. development	784[4]	814[4]	880	924	1600	1168	1478	1210
Sub-Total	4228	4374/4684	5900	5994	5339	5350	6052	6490
Development Cost[5]								
Airframe and avionics	681	742	890	1060	778	883	865	1050
Engines—excluding post-cert. development	371	450	700	360	980	450	1010	515
Sub-Total	1052	1192	1590	1420	1758	1333	1875	1565
Total Production plus Development Cost[6]	5280	5566/5876	7490	7414	7097	6683	7927	8055

[1]FAA provided two estimates, one with and one without Boeing's "proposed contingency" amount.

[2]PRC and ORI estimates are based upon the cost equations presented in their reports in Part III. These numbers will differ somewhat from those presented in their reports due to various revisions to conform to later developments.

[3]Boeing's estimate includes approximately $0.8 million per aircraft for profit and contingencies percentages taken on the engine. N... the other airframe estimates include explicit charges based upon the cost of the engines.

[4]... ectric includes one-half of the estimated post-certification development costs in its engine unit price; the remainder ... tely $162 million) General Electric proposes to charge against spare parts sales.

[5]... s estimate includes $56 million (about $0.3 million per aircraft) for profit. Profit is not included in any of the other development cost estimates. (Profit is included in the production cost estimates. Ten percent on costs is used as the profit rate for all production cost estimates except for General Electric's engine estimates which are based upon fifteen percent.)

[6]Spares, facilities and ground support equipment are not included in these costs.

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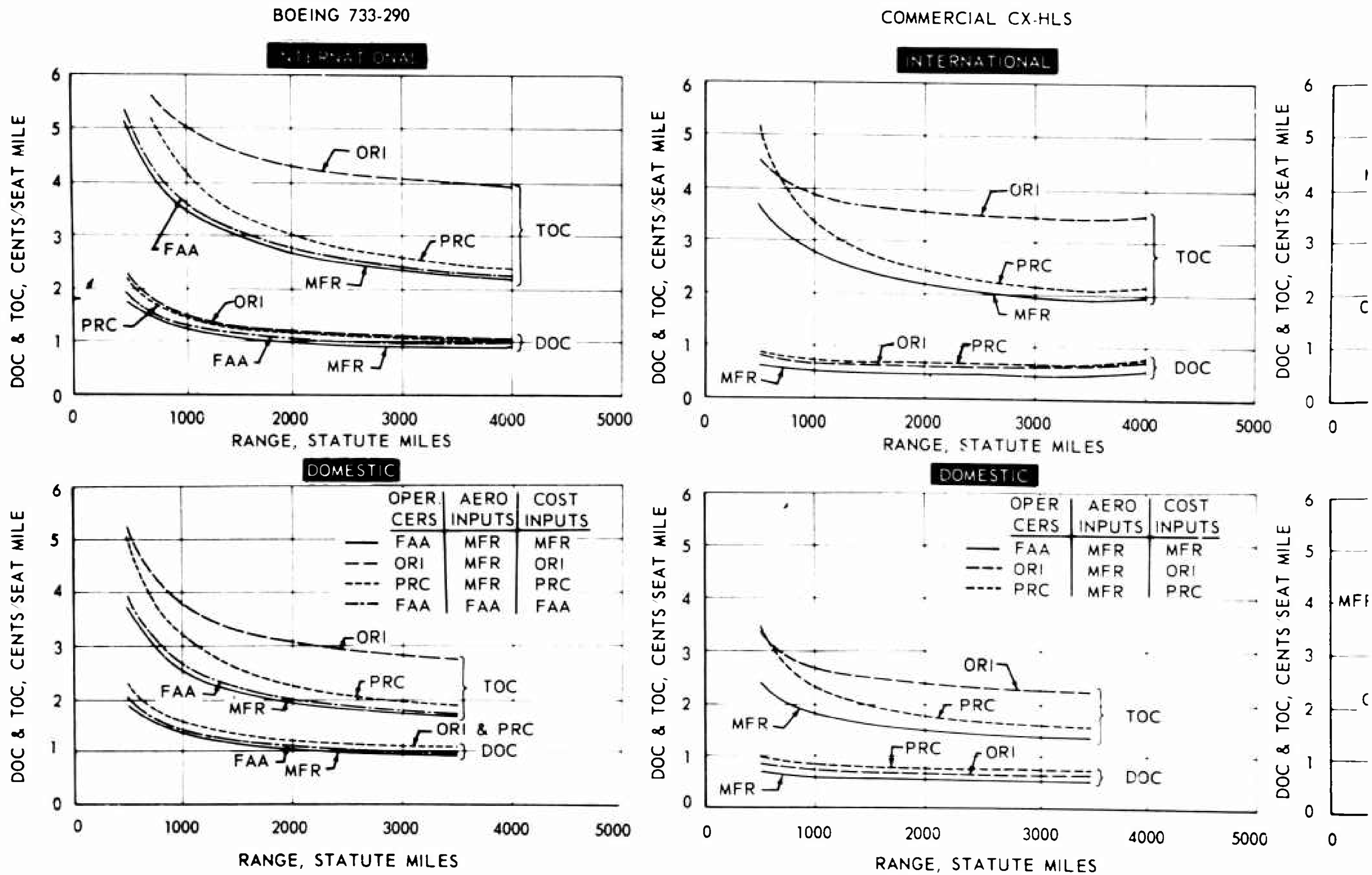

Figure A1-2. Total operating cost and direct operating cost per seat-mile versus range for the Boeing 733-290, commer

[redacted]

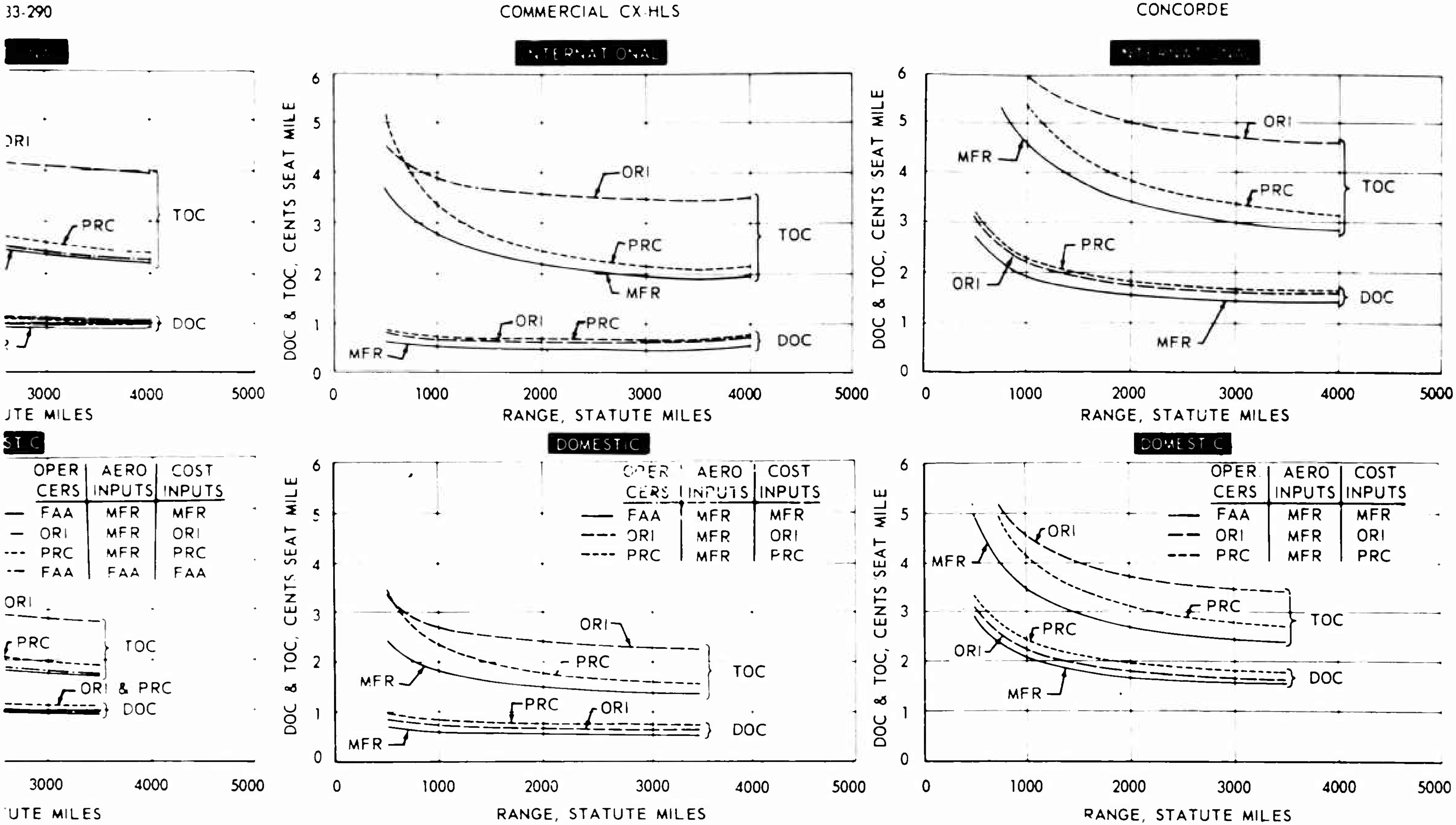

Figure VI-2 Total operating cost and direct operating cost per seat-mile versus range for the Boeing 733-290, commercial CX-HLS, and Concorde.

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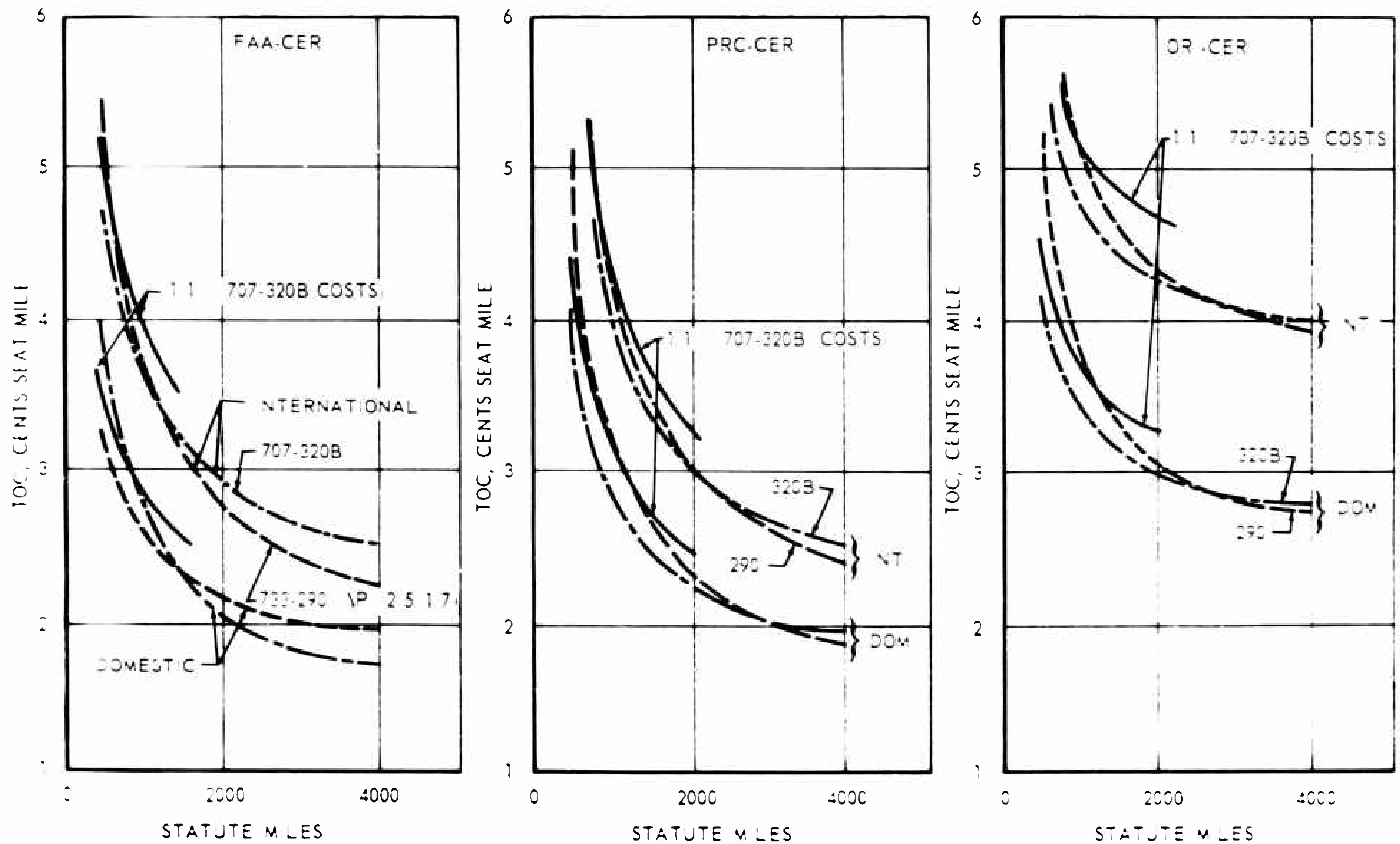

Figure A1-3 Comparative performance of various aircraft using alternative cost estimating relationships (CER)

In Figure A1.3 are shown comparative costs per seat-mile versus route distance for the Boeing 707-320B and the SST, using the various sets of estimating equations for both international and the domestic route segments. For comparative purposes, curves representing 1.1 times the total operating cost for the Boeing 707-320B are also shown. The aerodynamic inputs for the SST are those validated by the FAA. The SST sales price input for the PRC and ORI curves is that computed by means of the PRC and ORI production cost equations, respectively. The FAA curves are based on the FAA-validated price. Again, the variances between these results stem from differences in the sales price inputs used, and in the operating cost equations themselves. If a single sales price were used (e.g., that validated by the FAA), the variances in the route distance at which SST costs are equal to current jet costs would be greatly reduced. A large variance in indirect costs does remain, affecting the expected level of total operating costs. Further cost comparisons among the various aircraft will be drawn in estimating the market for aircraft (Section A2.2 below).

A1.4 KEY PERFORMANCE AND ENVIRONMENT PARAMETEPS

The results of any estimation procedure depend, to a very large extent, on the quality of inputs used. In the prediction of performance of any advanced aircraft, uncertainty exists as to the performance achievable. If good design and construction practices are used, the aircraft may achieve actual performance close to that estimated.

The more important performance parameters which can appreciably affect the economics of an aircraft are the following:

a. the lift-to-drag ratio of the aircraft,

b. the specific fuel consumption of the installed engine,

c. the actual thrust of the installed engine,

d. the weight of the aircraft.

The sensitivity analysis presented in Section A3 is made at the cost level. It is, of course, possible to perform the same sort of analysis at the level of the performance parameters. For example, one of the elements entering into operating cost is the fuel burned. The fuel burned depends on such parameters as the lift drag ratio and the specific fuel consumption. In subsequent analyses, the probable deviations in these parameters (both favorable and adverse) will be studied over the route system to determine the sensitivity of the results. Moreover, the aircraft must fly under real atmospheric conditions and not standard conditions. The effect of operating on a hot day (i.e., at an increment of 11° Centigrade above standard) will also be studied on a route system basis.

A2. ESTIMATING MARKETS FOR AIR TRANSPORT AND AIRCRAFT

The purpose of this section is to present the underlying rationale and principal results of projecting the demand for air transport, the derived demand for long-range aircraft, and the split of this aircraft market among flight equipment alternatives. Recognizing the uncertainties inherent in projecting the future, we have approached this task in several ways:

a. The growth of air transport over the period 1951-1964 was studied because it typifies more closely that for the next 15 years than does any other past period. The growth of air transport in the 1930s was strongly affected by the Depression and by the primitive technology then available. The decade of the 1940s, the war years and the early years of postwar reconstruction, could likewise not be termed typical. Projections of demand for air transport were then made on the basis of both time series and cross-section analyses.

b. The projection of the total market for long-range aircraft and the split among alternatives was made in several ways:

1) by extrapolating recent data relating to scheduled flight frequencies and their associated fleet requirements, and then reasoning on the basis of comparative costs and yields to airlines and of attractiveness to air travelers.

2) by utilizing several analytical aids (or route simulations) which embody more detail on comparative costs and yields, and on attractiveness to air travelers. These aids were developed under contract by Operations Research, Incorporated (ORI) and by the National Bureau of Standards (NBS).

A2.1 DEMAND FOR LONG-RANGE AIR TRANSPORT[1]

In making market projections, we focus attention primarily on the period 1965-1980:

1965-1972 — the period, preceding availability of the newer aircraft, during which present fleets will be expanded to meet rapidly growing traffic needs.

1972-1980 — the period of large-scale reequipment of Free World fleets with newer aircraft.

Provided their economics are favorable, the newer transports will find increasing use over the period 1980-1990 as the growth of air transport continues. Accordingly, our projection of air transport will encompass the entire 25-year period from 1965 to 1990, with primary focus on the first 15 years.

[1]As earlier defined, long-range air transport includes all transportation of passengers, cargo, freight, and mail over route distances greater than 900 statute miles. A few routes of shorter distance are included as tag-end routes.

[redacted]

Even if the current Free World route structure changes relatively little over the forecast period, the services offered are likely to undergo substantial change. These changes are expected to derive from improvements in flight equipment, continuing decreases in the price of service, and increases in the number and buying power of users of air transport. Although the growth rate of air transport may slacken somewhat as the industry matures, the airlines generally anticipate a rate continuing significantly higher than that of the Free World economy.

Airline revenues in the post-Korea period show growth rates of cargo and freight closely comparable to those for passenger traffic. Total revenues are therefore assumed to continue to increase directly with the growth in passenger revenues. Increasing fleet requirements will be provided by current and growth aircraft types until newer ones become available, probably in the early 1970s. Expansion may then involve newer aircraft types—the supersonic transport and/or the advanced subsonic transport. The expected number of aircraft in the fleets of the Free World carriers will be assumed to vary with the number of seat-miles to be produced.

The demand forecast presented here was first computed from a consideration of traffic data alone. The results were then analyzed and related to various important socio-economic variables (e.g., income, price, population), together with their respective projections into the future. The traffic forecast derived through the time series approach was complemented by the cross-section approach used by our demand contractor, Systems Analysis and Research Corporation (SARC). SARC results are presented in Part III of this report.

The relevant data for analysis are, accordingly, Free World revenue passenger-miles (RPM) as reported by the International Civil Aviation Organization (ICAO). Table A2.1 shows that Free World air transport has grown almost 5-fold in these 14 years. Total RPM in scheduled services increased from 21.7 billions in 1951 to 107 billions in 1964. While air transport growth has indeed been rapid, it has proceeded at a gradually decreasing rate.[1] This is evident in column (5), showing the average rate by year cumulatively since 1951. The basic assumption underlying our projection for air transport, and hence for aircraft, is that this pattern of growth will persist into the future. Note that a degree of conservatism has been deliberately introduced here. Long-range traffic has been growing more rapidly than short-range. By using total Free World RPM rather than long-range RPM to forecast traffic, the market for long-range aircraft will be somewhat understated.

Figure A2.1 shows the annual growth rate of Free World air transport. Except for two years (4.44 percent growth in 1957-1958, a year of recession; and 7.18 percent growth in 1960-1961, a year of recession and of fare increases), the growth rate ranged from 11.4 to 17.3 percent. The least-squares best-fit trend line through these data produces the "base" projection for the period 1965-1990 shown in Figure A2.1 and in Table A2.2. The average annual base growth rate over the period 1965-1980 is 9.2 percent; for 1965-1990, 8.2 percent.

This projection indicates a gradual maturation of the air transport industry. Also shown in Figure A2.1 are projections of a "high" growth rate averaging 10 percent (1965-1990), and a "low" rate averaging 6 percent. The projections of Free World revenue passenger-miles (1965-1990) at the base rate of growth are shown in Figure A2.2, and

[1]Note in column 4 of Table A2.1 that the annual growth rate has been increasing for the past three years.

Table A2.1. Free World Revenue Passenger-Miles (1951-1964)

Date	Revenue passenger-miles (billions)	Increase over previous year		Average annual growth rate over 1951 Percentage
		Passenger-miles (billions)	Percentage	
(1)	(2)	(3)	(4)	(5)
1951	21.685	--	--	--
1952	25.104	3.419	15.77	15.77
1953	28.908	3.804	15.15	15.46
1954	32.501	3.593	12.43	14.44
1955	38.128	5.622	17.30	15.15
1956	44.162	6.039	15.84	15.29
1957	50.607	6.445	14.50	15.17
1958	52.853	2.246	4.44	13.57
1959	60.555	7.702	14.57	13.70
1960	67.733	7.178	11.85	13.49
1961	72.597	4.864	7.18	12.84
1962	80.896	8.299	11.43	12.72
1963	91.494	10.598	13.10	12.75
1964	107.0	15.5	16.94	13.06

Source: International Civil Aviation Organization, Digest of Statistics No. 100, p. 12. Data for 1964 from I.C.A.O. as reported in the New York Times, December 30, 1964.

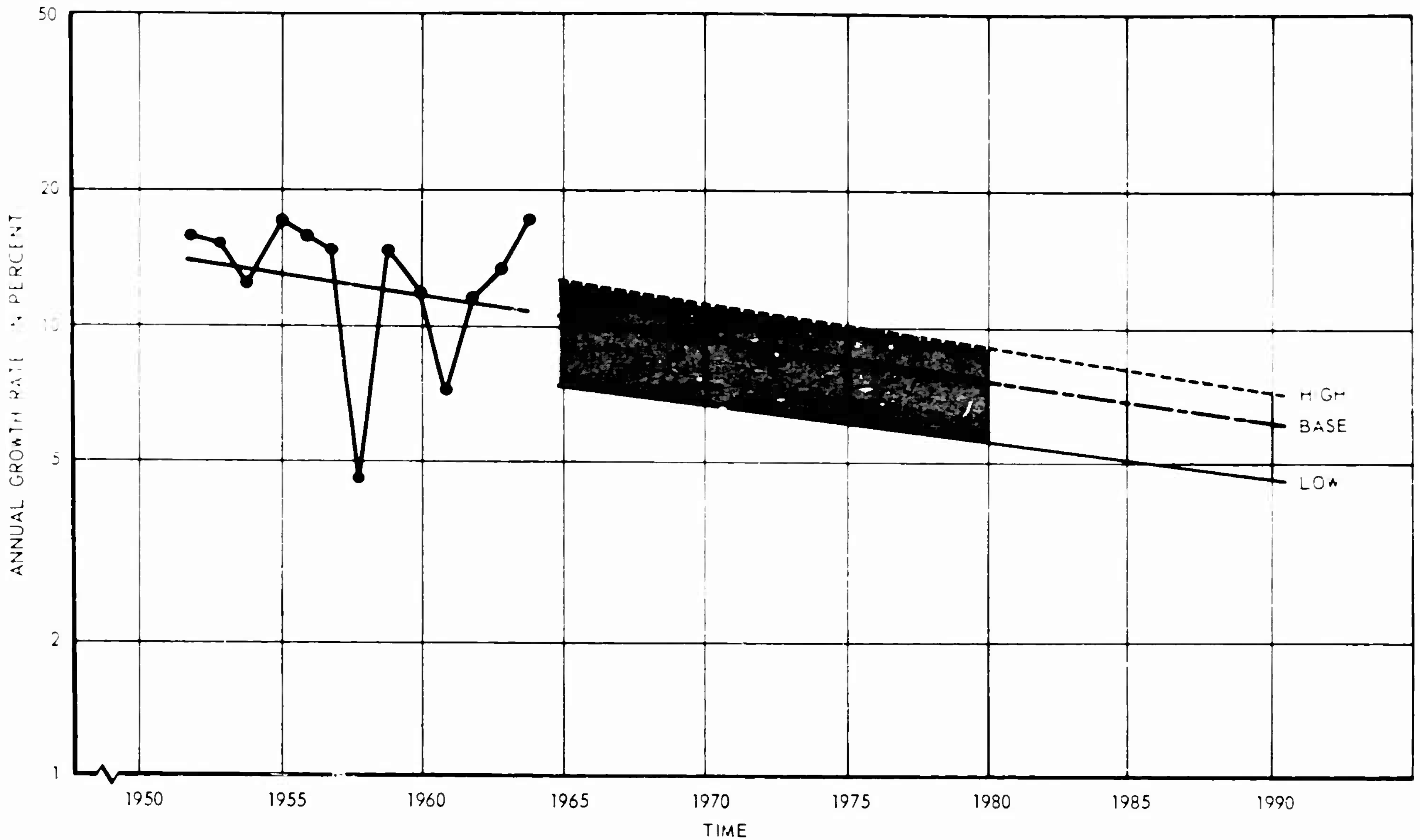

Figure A2.1. Annual percentage rates of growth of Free World air transport: 1951–1964 actual and 1965–1990 projected.

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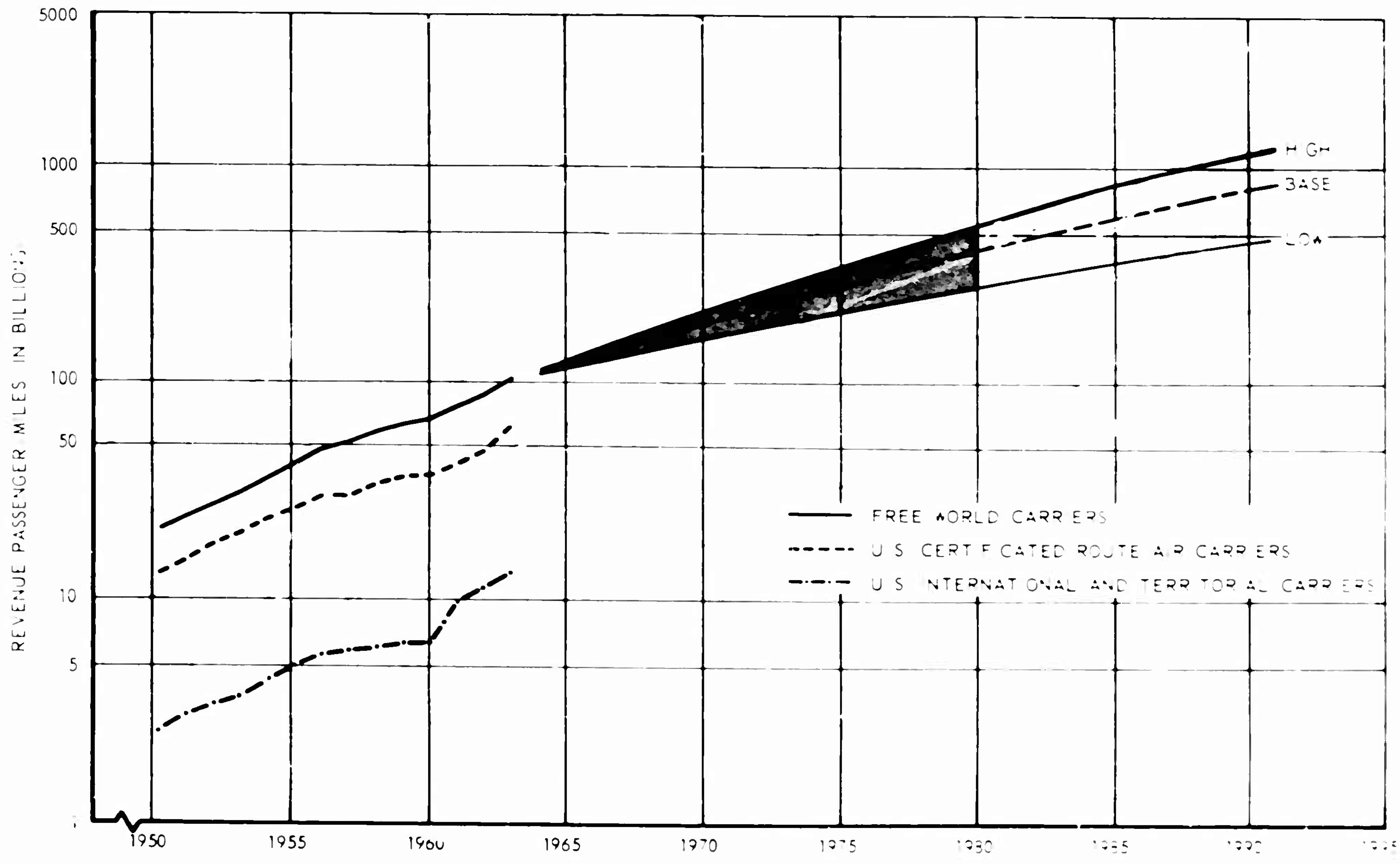

Figure A2.2 Growth in air transport 1951–1963 [illegible]

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listed in Table A2.2. The relative market size in 1980 is expected to be 4.07 times greater than 1964, amounting to 436 billion RPM. The corresponding projections at the low and high rates of growth are also shown in Figure A2.2, and listed in Tables A2.3 and A2.4, respectively. The range in relative market size in 1980 is expected to be 3.10 to 5.31, amounting to 332 to 568 billion RPM.

Commentary on Demand Projections

The growth rates are projected from data which reflect the complex interaction of many underlying forces: the East-West political climate, the general economic conditions in the Free World, the progress in air transport, and changes in income, population and other socio-economic factors. We must now ask whether these underlying forces are likely to change, and in what direction. The following assumptions are implicit in our forecast:

a. Cold War tensions will continue, with only moderate abatement.

b. Economic growth of the Free World will continue at approximately the same rates as in the base period. One important difference could be a smaller amplitude in the cyclic behavior of the Free World economy, and hence a lower drag on average growth rates.

The rate of growth will then depend basically on two sets of factors:

a. The price and quality of air transport services offered.

b. The number and income of potential users.

The price of air transport services (in real terms) has been falling at an average rate of 1.4 percent per year over the

Table A2.2. Air Traffic Projections at "Base" Rate of Growth for Free World Revenue Passenger-Miles (1965-1990)

Date (1)	Percent increase (2)	Passenger-miles (billions) (3)	Passenger-miles Relative 1964 = 1.00 (4)
1965	10.701	118.5	1.107
1966	10.477	130.9	1.223
1967	10.258	144.3	1.349
1968	10.043	158.8	1.484
1969	9.833	174.4	1.630
1970	9.627	191.2	1.787
1971	9.425	209.2	1.955
1972	9.228	228.5	2.136
1973	9.035	249.1	2.328
1974	8.845	271.1	2.534
1975	8.660	294.6	2.753
1976	8.479	319.6	2.987
1977	8.301	346.1	3.235
1978	8.127	374.2	3.497
1979	7.957	404.0	3.776
1980	7.790	435.5	4.070
1981	7.627	468.7	4.380
1982	7.467	503.7	4.707
1983	7.311	540.5	5.051
1984	7.158	579.2	5.413
1985	7.008	619.8	5.793
1986	6.861	662.3	6.190
1987	6.717	706.8	6.606
1988	6.577	753.3	7.040
1989	6.439	801.8	7.493
1990	6.304	852.3	7.965

Table A2.3. Air Traffic Projections at "Low" Rate of Growth for Free World Revenue Passenger-Miles (1965-1990)

Date (1)	Percent increase (2)	Passenger-miles (billions) (3)	Passenger-miles Relative 1964 = 1.00 (4)
1965	8.561	116.2	1.085
1966	8.382	125.9	1.177
1967	8.206	136.2	1.273
1968	8.034	147.1	1.375
1969	7.866	158.7	1.483
1970	7.702	170.9	1.597
1971	7.540	183.8	1.718
1972	7.382	197.4	1.845
1973	7.228	211.7	1.979
1974	7.076	226.7	2.119
1975	6.928	242.4	2.265
1976	6.783	258.8	2.419
1977	6.641	276.0	2.579
1978	6.502	293.9	2.747
1979	6.366	312.6	2.921
1980	6.232	332.1	3.104
1981	6.102	352.4	3.293
1982	5.974	373.5	3.491
1983	5.849	395.3	3.694
1984	5.726	417.9	3.906
1965	5.606	441.3	4.124
1986	5.489	465.5	4.350
1987	5.374	490.5	4.584
1988	5.262	516.3	4.825
1989	5.151	542.9	5.074
1990	5.043	570.3	5.330

Table A2.4. Air Traffic Projections at "High" Rate of Growth for Free World Revenue Passenger-Miles (1965-1990)

Date (1)	Percent increase (2)	Passenger-miles (billions) (3)	Passenger-miles Relative 1964 = 1.00 (4)
1965	12.841	120.7	1.128
1966	12.572	135.8	1.269
1967	12.310	152.5	1.425
1968	12.052	170.9	1.597
1969	11.780	191.0	1.785
1970	11.552	213.1	1.992
1971	11.310	237.2	2.217
1972	11.074	263.5	2.463
1973	10.842	292.1	2.730
1974	10.614	323.1	3.020
1975	10.392	356.7	3.334
1976	10.175	393.0	3.673
1977	9.961	432.1	4.038
1978	9.752	474.2	4.432
1979	9.548	519.5	4.855
1980	9.348	568.1	5.309
1981	9.152	620.1	5.795
1982	8.960	675.7	6.315
1983	8.773	735.0	6.869
1984	8.590	798.1	7.459
1985	8.410	865.2	8.086
1986	8.233	936.4	8.751
1987	8.060	1011.9	9.457
1988	7.892	1091.8	10.204
1989	7.727	1176.2	10.993
1990	7.565	1265.2	11.824

past decade,[1] because productivity has been growing more rapidly than the costs of providing service. As the Free World carriers augment and modernize their fleets, the productivity is expected to continue increasing more rapidly than costs. Hence, the price of air transport is expected to continue falling, but possibly at a declining rate. The quality of services in terms of speed, safety, scheduling convenience, and comfort is expected to continue to improve.

With the growing affluence of the industrialized nations, the pool of potential users may be expected to continue to grow at a high rate. Moreover, the rate of growth of this pool will be augmented by increasing mobility and leisure, and the lessening fear of air travel.

The independently derived estimate of our demand contractor (SARC), also showed a gradually maturing industry with an average annual increase (1963-1990) in revenue passengers of 6.2 percent. However, SARC assumed no change in the real price of air transport. When adjusted to allow for the expected continuing decrease in airline fares and the increase in average trip distance, the corresponding SARC estimate of revenue passenger-miles would then approximate the base estimate which was derived by the SST study staff. The range of growth rates used in our analysis (6 to 10 percent, with a base of 8 percent) has been discussed in detail with several major U.S. carriers. For the most part, the domestic carriers feel that, for their route structures, a 5.5 to 9.5 percent range of growth rate is quite probable; the international carriers, 8 to 12 percent.

[1]Prices fell during the years 1951-1957 and 1963, and rose during 1958-1962.

A2.2 SIMPLIFIED METHOD OF ESTIMATING AIRCRAFT MARKET

A method of estimating the market which involves only a few gross assumptions and a minimum of calculation will now be described. This simplified method is useful in interpreting the results of more complex analyses. It involves the following steps:

Route Analysis

a. Extrapolating actual 1964 flight-frequency data for 154 selected major city-pairs in accordance with the growth rates earlier derived,

b. Computing the associated air fleet requirements,

Rationale for Choice

c. Reasoning on the basis of comparative costs and yields to airlines and of relative attractiveness to travelers to determine the extent to which a newer aircraft may displace the current subsonic jets.

This method parallels the reasoning used by airline managements in making their flight equipment decisions. The estimates of the aircraft market made by this simplified method have been substantiated by the route simulations, which provide a more detailed representation of the market.

Route Analysis

For any given schedule of flight frequencies between specific city-pairs, one can readily determine the seat-mile capacity required to provide the desired level of service. In performing this route analysis, the following assumptions are made:

a. To simplify the route system to be considered, the Free World is divided into 67 regions, identical to those used in the National Bureau of Standards (NBS) and Operations Research, Incorporated (ORI) simulation studies. Fuel stops at Nandi, Thule, and Goose Bay are included, when necessary.

b. Only those city-pairs are used which are served by at least one jet flight per week and are separated by non-stop distances between 900 and 4000 statute miles. A few city-pairs separated by less than 900 statute miles are used where necessary to tie routes together. The result is a set of 154 city-pairs suitable for SST traffic.

c. The frequency of subsonic jet service in the summer of 1964 is taken as an indication of the relative importance of the several markets. This relative importance is assumed to persist throughout the forecast period.

d. The average aircraft utilization is 9 hours per day (3285 hours per year), which is approximately that currently being achieved on a system basis.

e. In all cases (except Case I described below) the newer aircraft replace the current subsonic jets on a seat-for-seat basis.

f. Block times[1] and distances are based on a standard day, no-wind conditions.

[1]Block time is the elapsed time between the removal of wheel blocks at the originating city and the placement of blocks at the terminating city.

Figures A2.4 through A2.7 illustrate several possible route systems served by the supersonic transport under various assumptions as to displacement of the subsonic jet, and assuming sonic boom effects are negligible.

Case I (Figure A2.3) shows the route system that would be served by the SST if its operating performance relative to the subsonic jet were quite poor. A very small number of supersonic transports might then find their way into service.

Case II (Figure A2.4) shows the route system served if the performance of the SST were sufficiently good to displace the subsonic jets in all city-pairs separated by at least 3000 statute miles (but less than 4000), as well as those for Case I. The routes now include the principal "gateway" cities separated by water.

Case III (Figure A2.5) shows the route system served if the SST displaces the subsonic jet in all city-pairs separated by at least 2000 statute miles, as well as those for Cases I and II. These now include the principal U.S. intercontinental routes.

Case IV (Figure A2.6) shows the route system served if the SST displaces the subsonic jets in all city-pairs separated by at least 900 statute miles. All 154 markets would now be served by the SST.

These four cases illustrate a spectrum of possible outcomes for the SST Program ranging from the rather poor market situation represented by Case I to the highly successful Case IV. The market impact of sonic boom is considered briefly below, and in more detail in Section A4.

Miami - New York
Los Angeles - Chicago
San Francisco - Chicago
Rome - Beirut
London - New York
Los Angeles - New York
San Francisco - New York
Honolulu - Los Angeles
Manila - Tokyo
Paris - New York
Honolulu - San Francisco
Bangkok - Manila
Chicago - Miami
Anchorage - Seattle
Los Angeles - Washington
Bombay - Bangkok
Mexico City - Los Angeles
Nairobi - Cairo
Madrid - New York
Tokyo - Honolulu
London - Montreal
Miami - Washington
Paris - Beirut
Beirut - Bombay
Cairo - Rome
London - Washington
Paris - Washington
Johannesburg - Nairobi
San Francisco - Washington
Seattle - New York
Mexico City - Chicago
Nandi - Sydney
Nandi - Honolulu
Cairo - Bombay

Dakar - Rio de Janeiro
Dakar - Madrid
Caracas - New York
Los Angeles - Miami
Johannesburg - Leopoldville
Caracas - Rio de Janeiro
Manila - Sydney
Dakar - Leopoldville
Mexico City - Montreal
Tokyo - Anchorage
Dakar - London
Honolulu - Seattle
Rome - London
Madrid - Rome
Rome - Paris
Goose Bay - Los Angeles
Goose Bay - London
Chicago - New York

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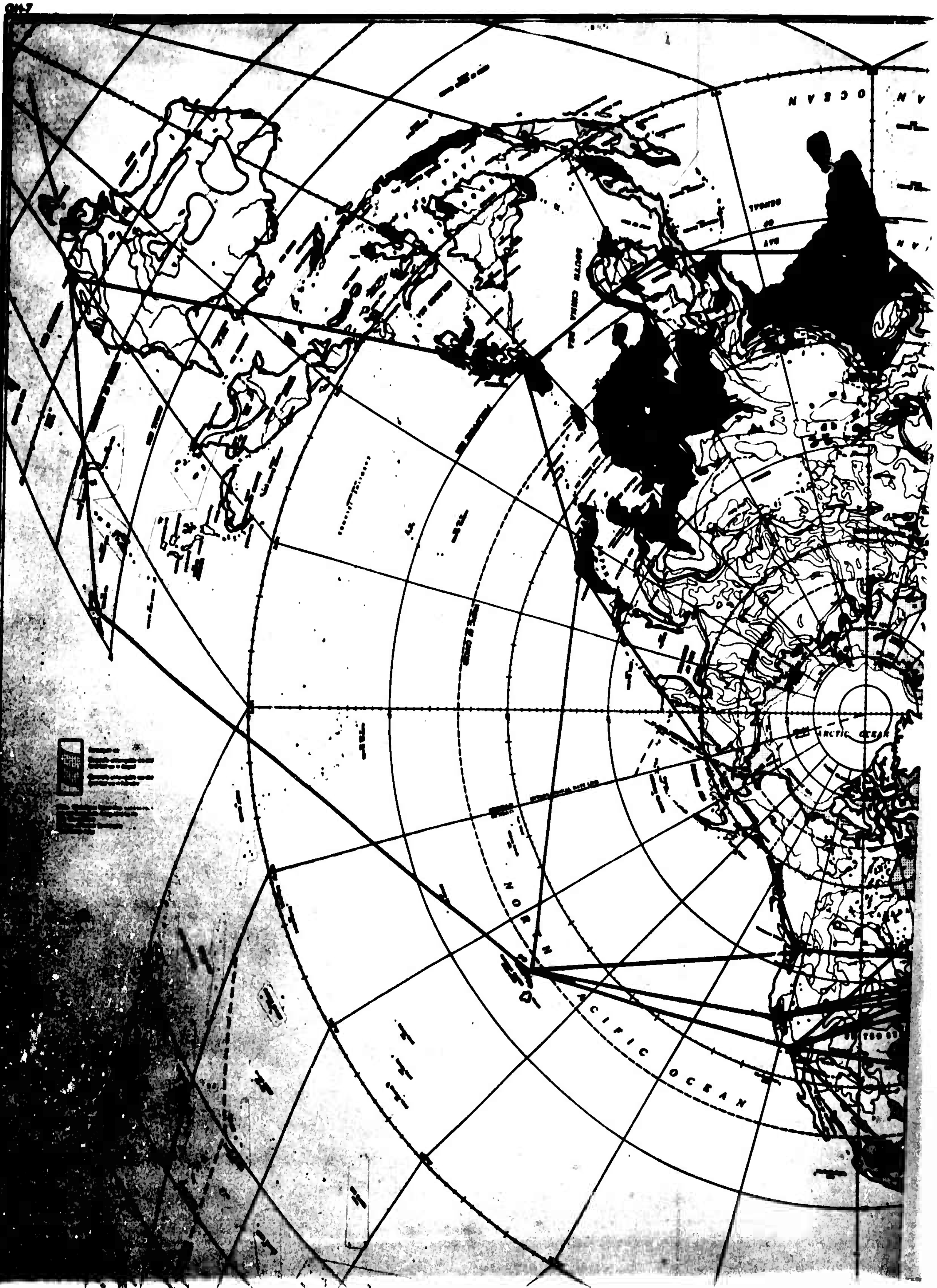

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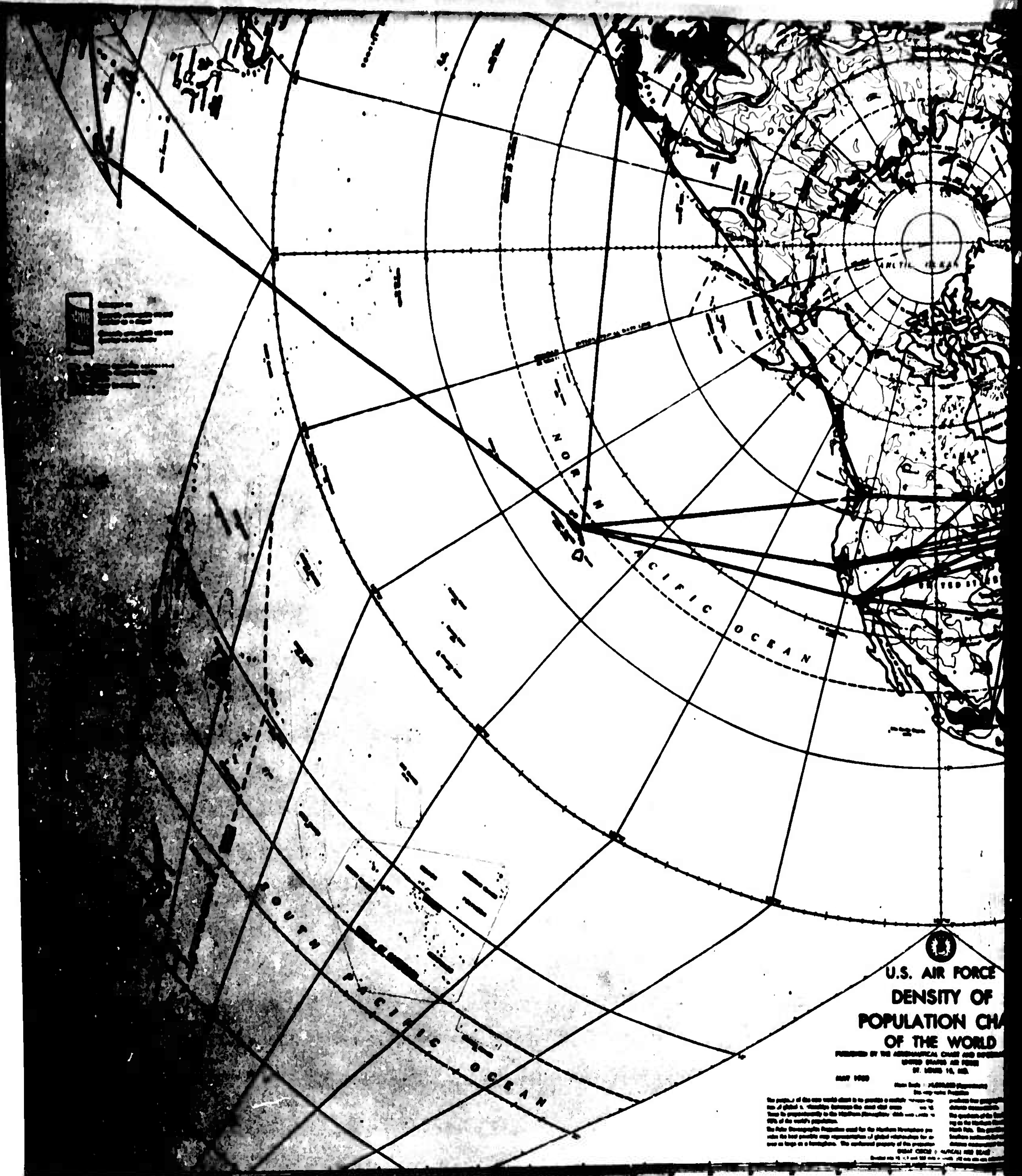

Figure A2.3. Case I.

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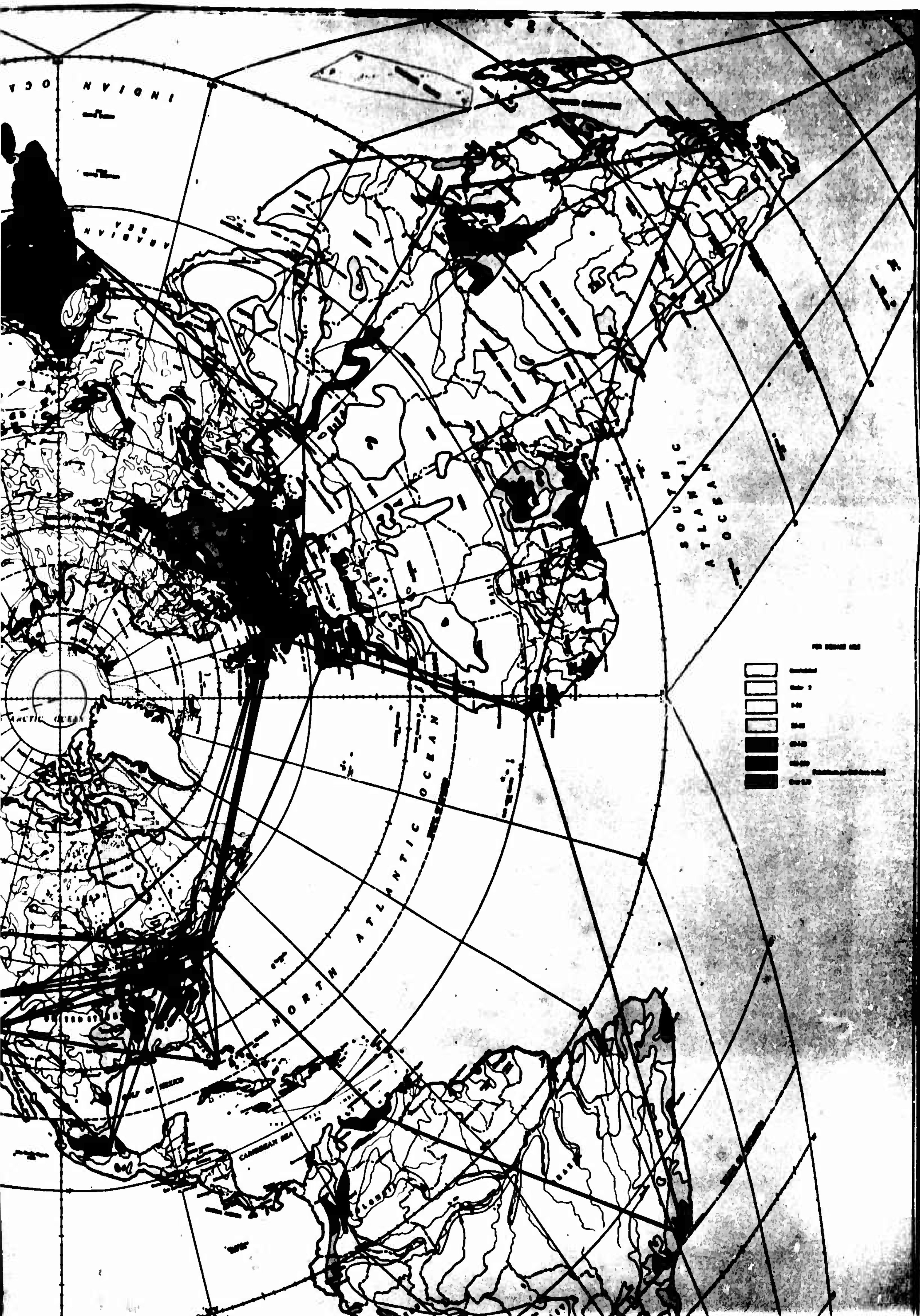

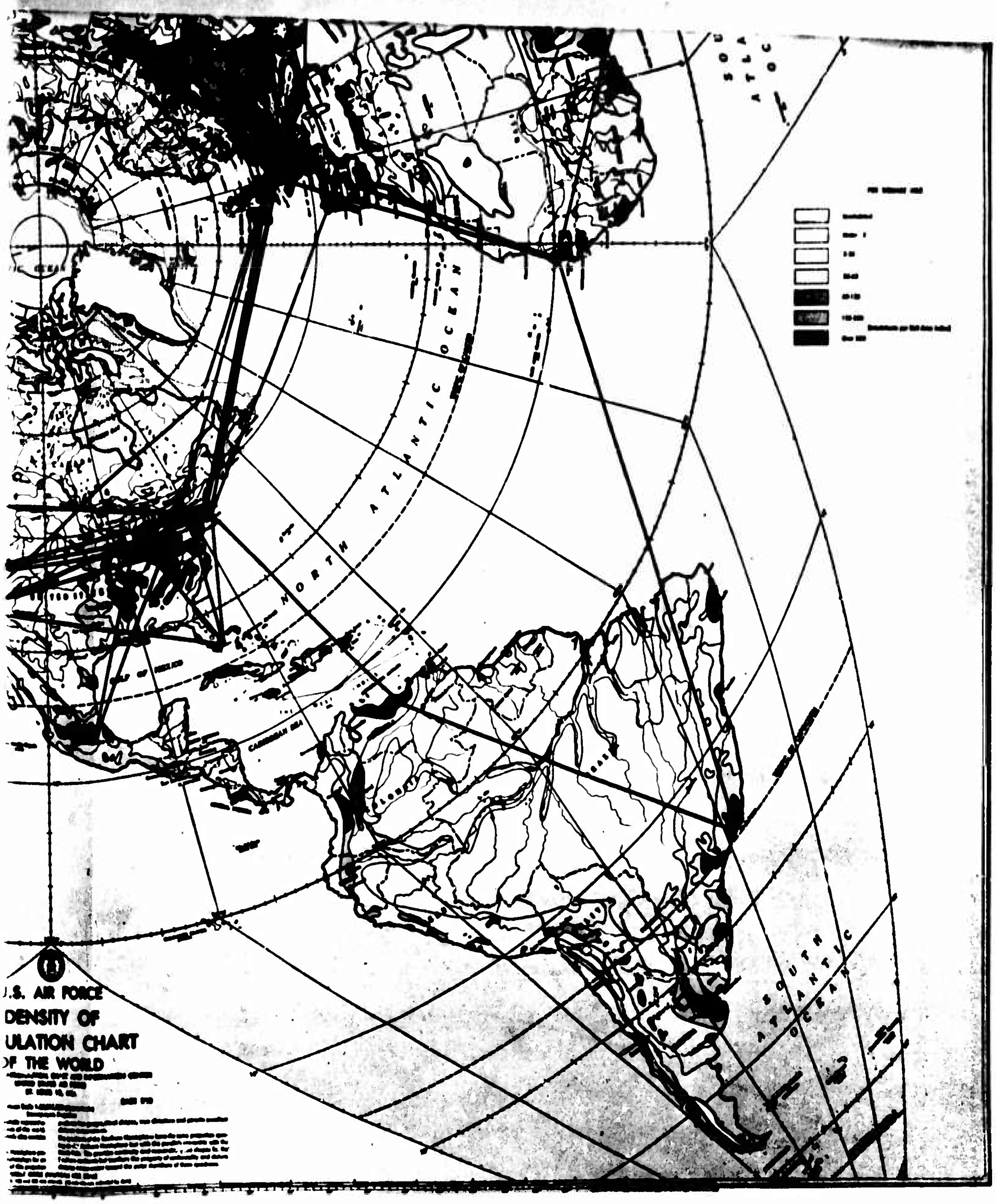
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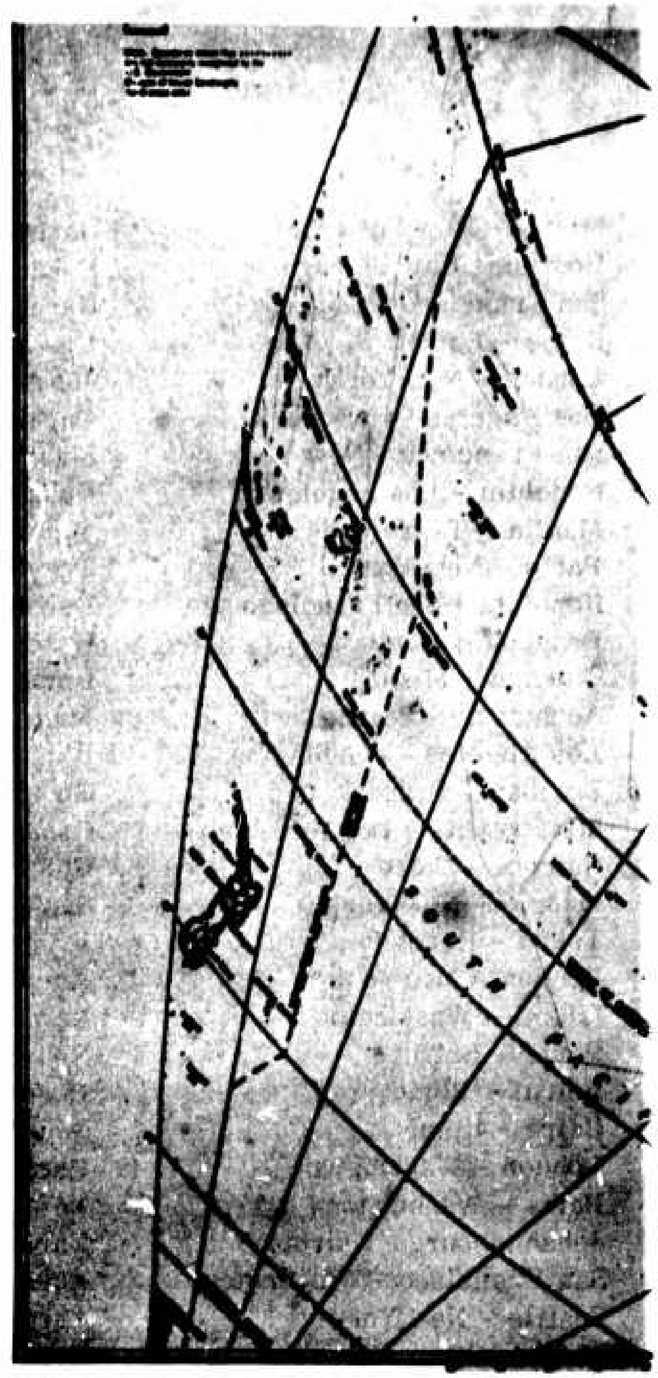

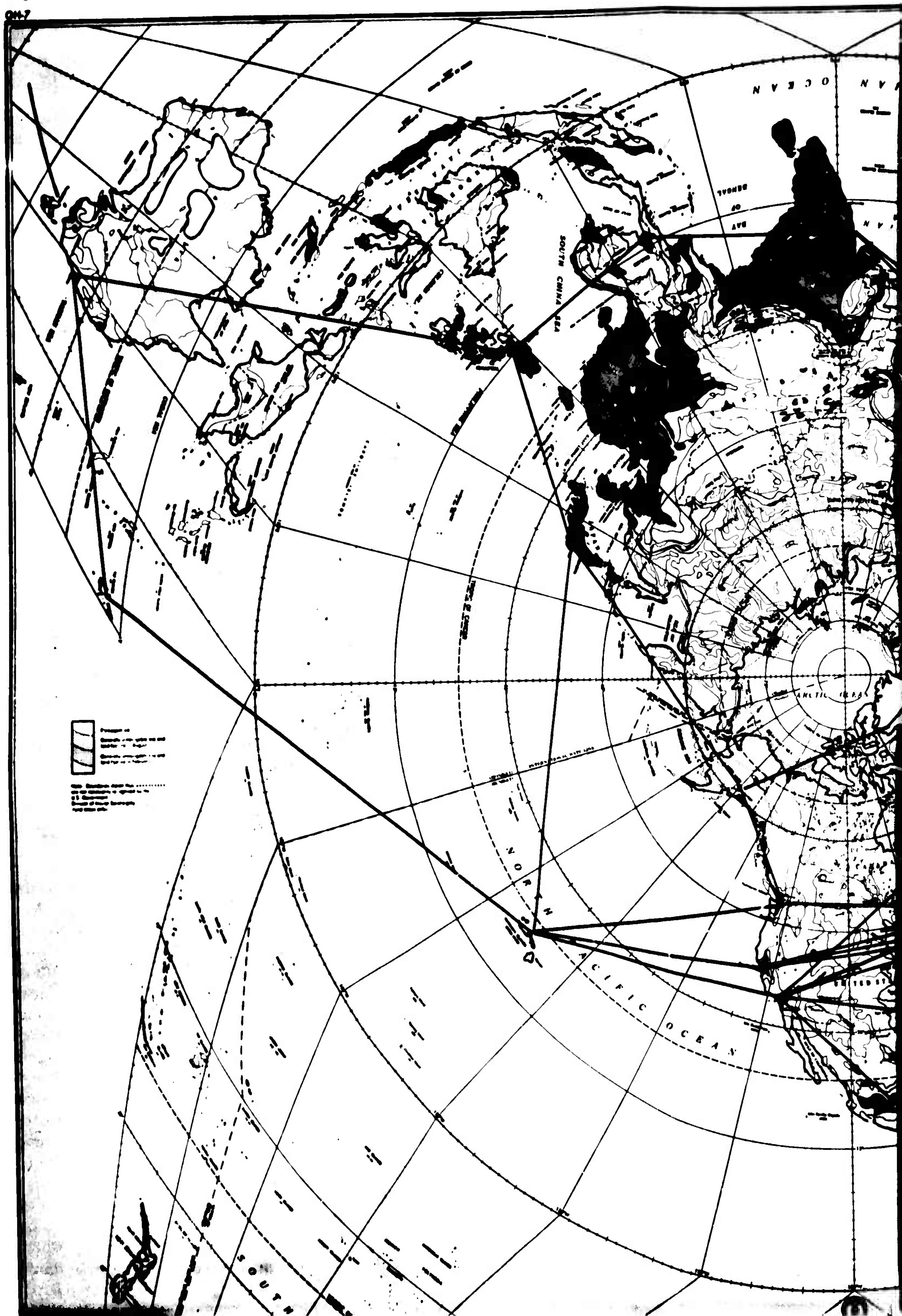

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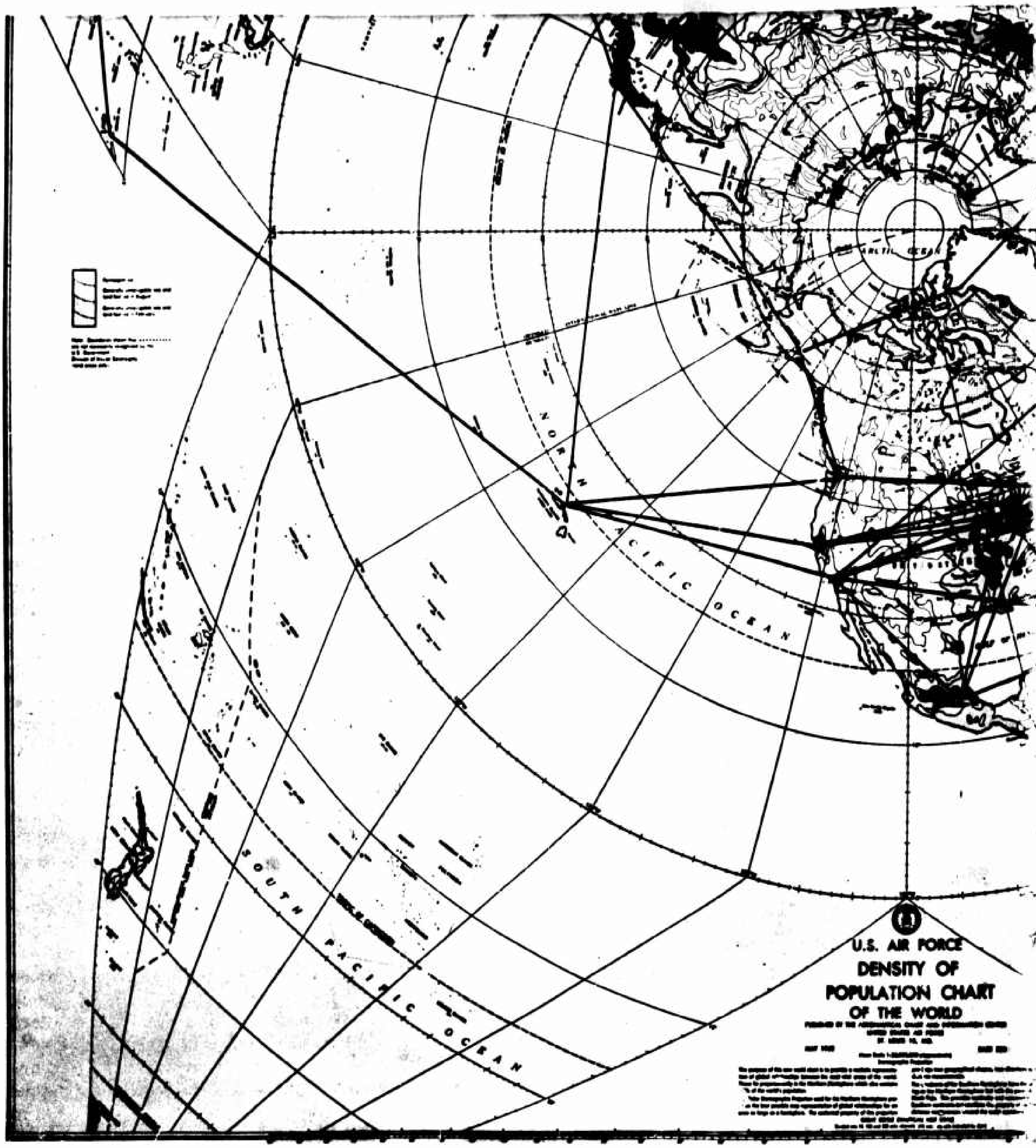

Figure A2.4. Case II.

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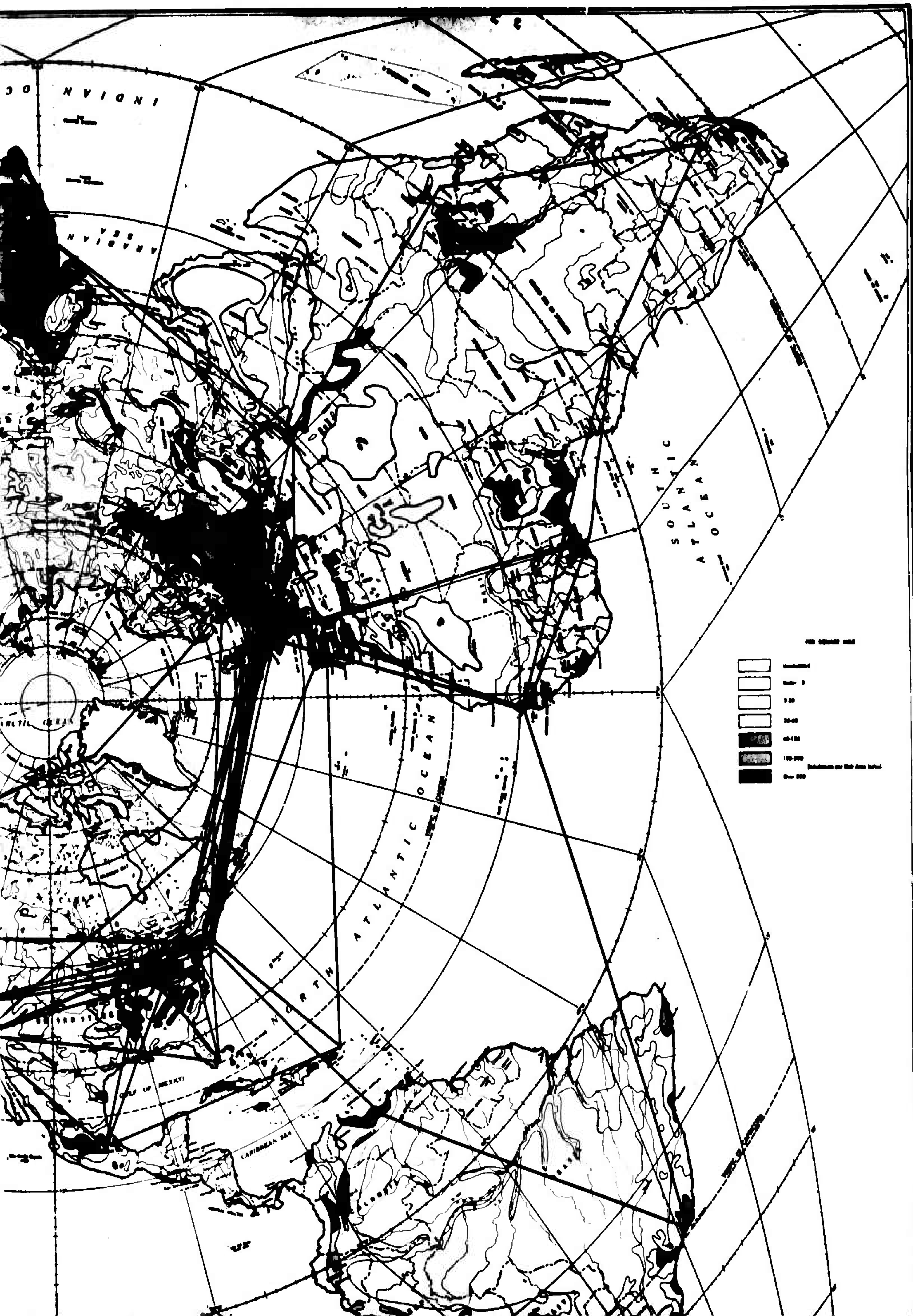

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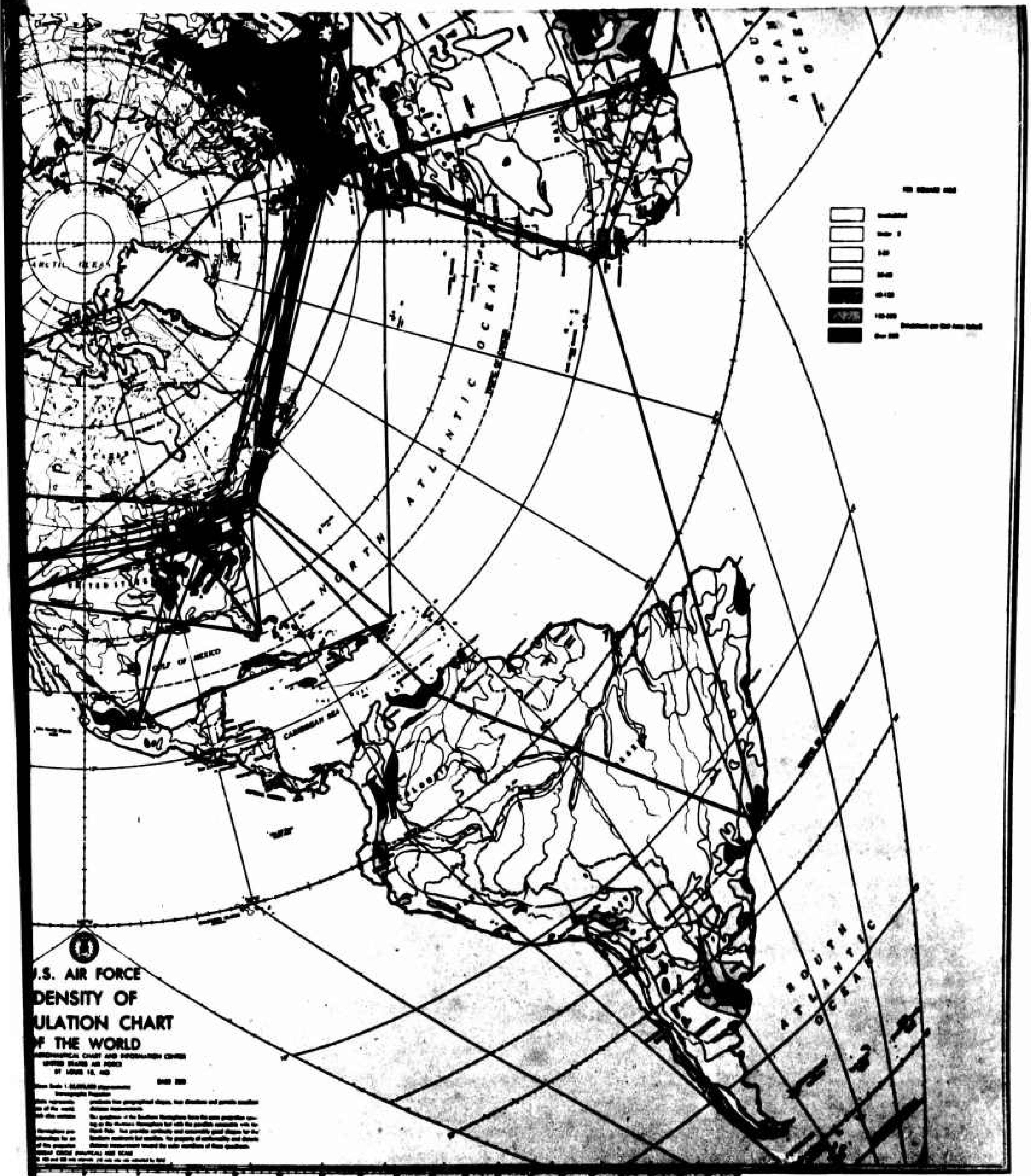
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Honolulu - San Francisco
Bangkok - Manila
Chicago - Miami
Anchorage - Seattle
Los Angeles - Washington
Bombay - Bangkok
Mexico City - Los Angeles
Nairobi - Cairo
Madrid - New York
Tokyo - Honolulu
London - Montreal
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Paris - Washington
Johannesburg - Nairobi
San Francisco - Washington
Seattle - New York
Mexico City - Chicago
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Manila - Sydney
Dakar - Leopoldville
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Madrid - Rome
Rome - Paris
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Frankfurt - New York
Amsterdam - New York
New York - Shannon
New York - Copenhagen
Boston - London
Madrid - San Juan
Paris - Montreal
New York - Brussels
Zurich - New York
Accra - Dakar
Cairo - Frankfurt
Brussels - Montreal
Amsterdam - Montreal
Mexico City - San Juan
Accra - London

Copenhagen - Madrid
Accra - Leopoldville
Thule - Copenhagen
Thule - Anchorage
Bombay - Baghdad
Mexico City - Lima
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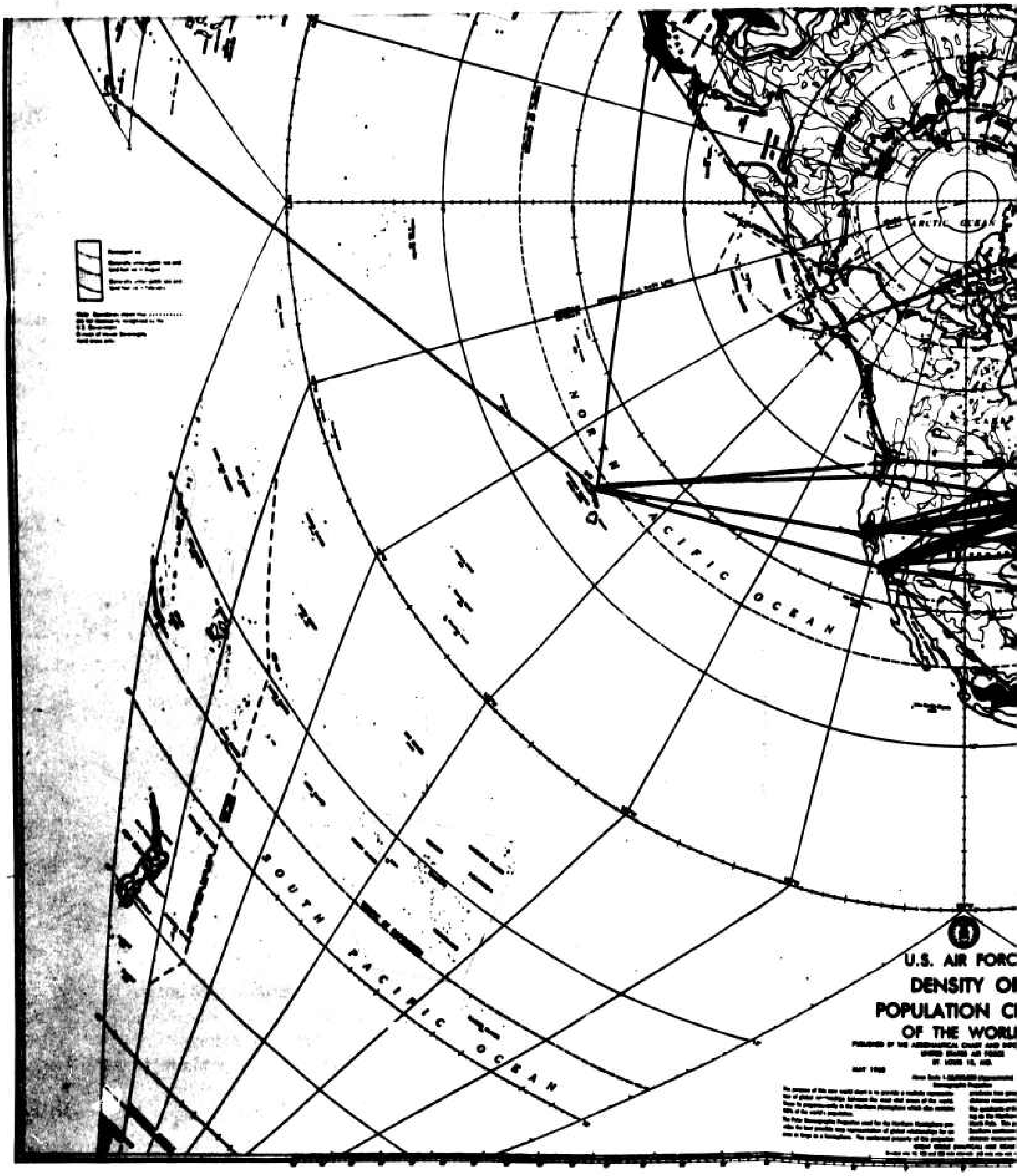

Figure A2.5. Case III.

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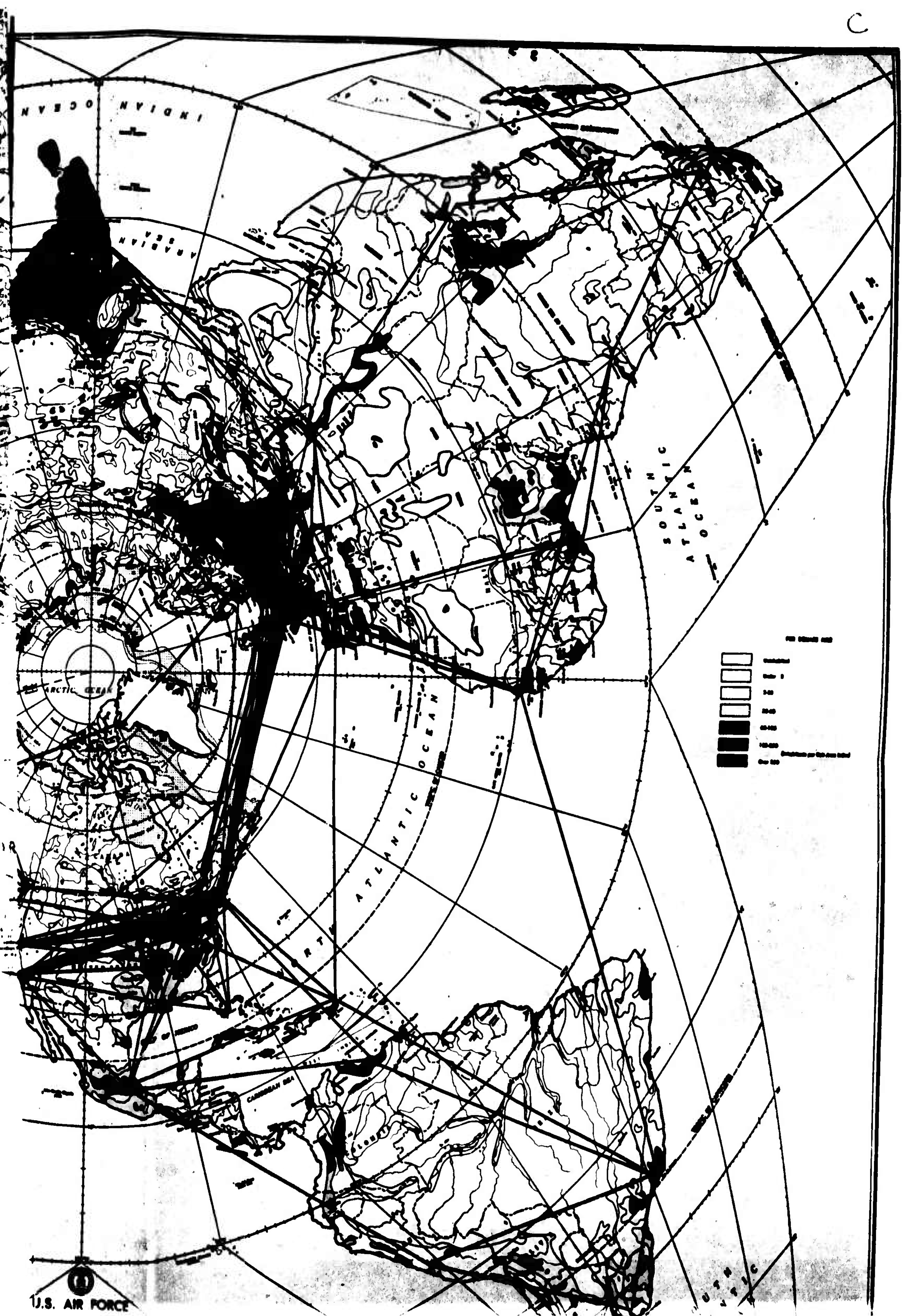
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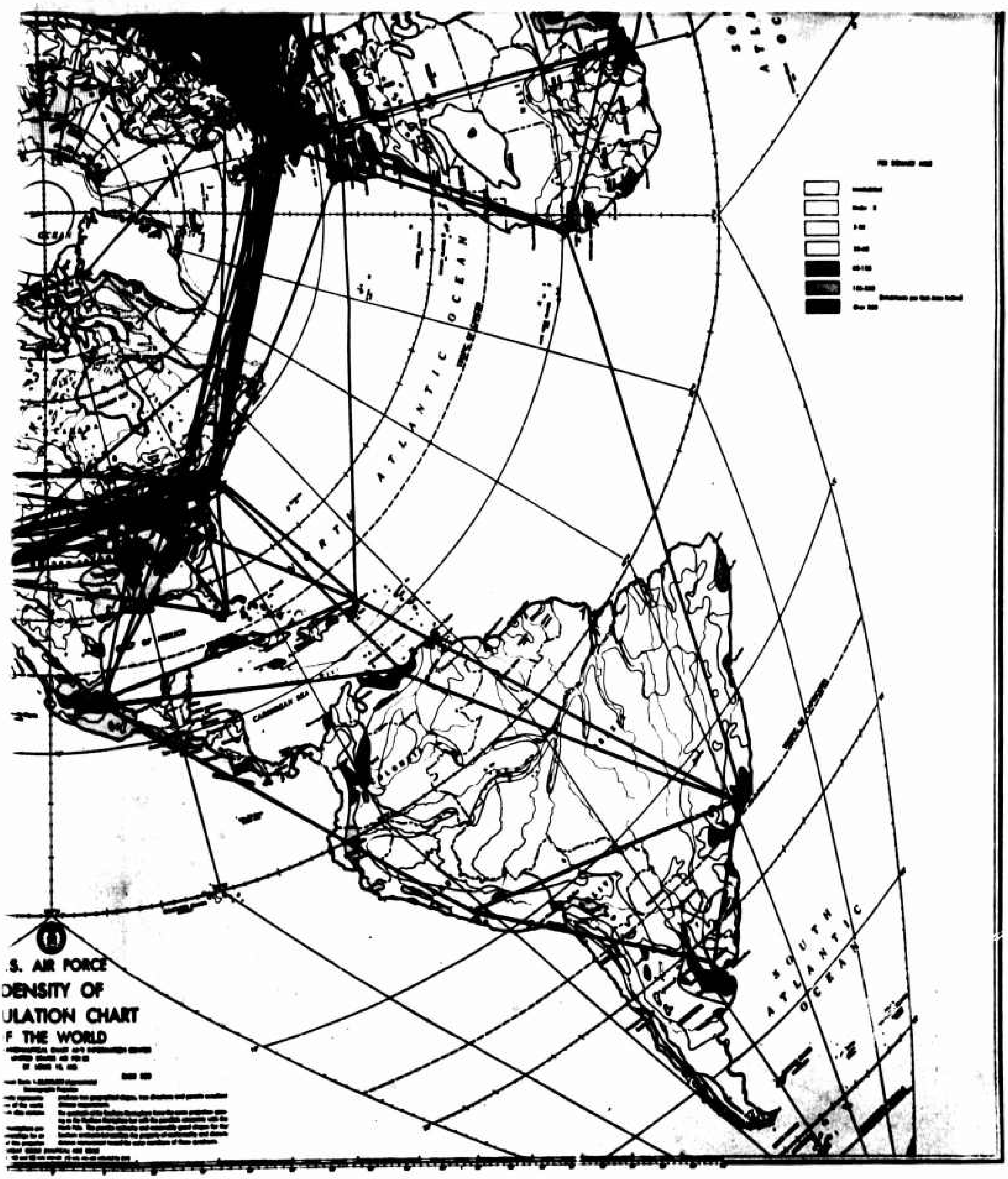

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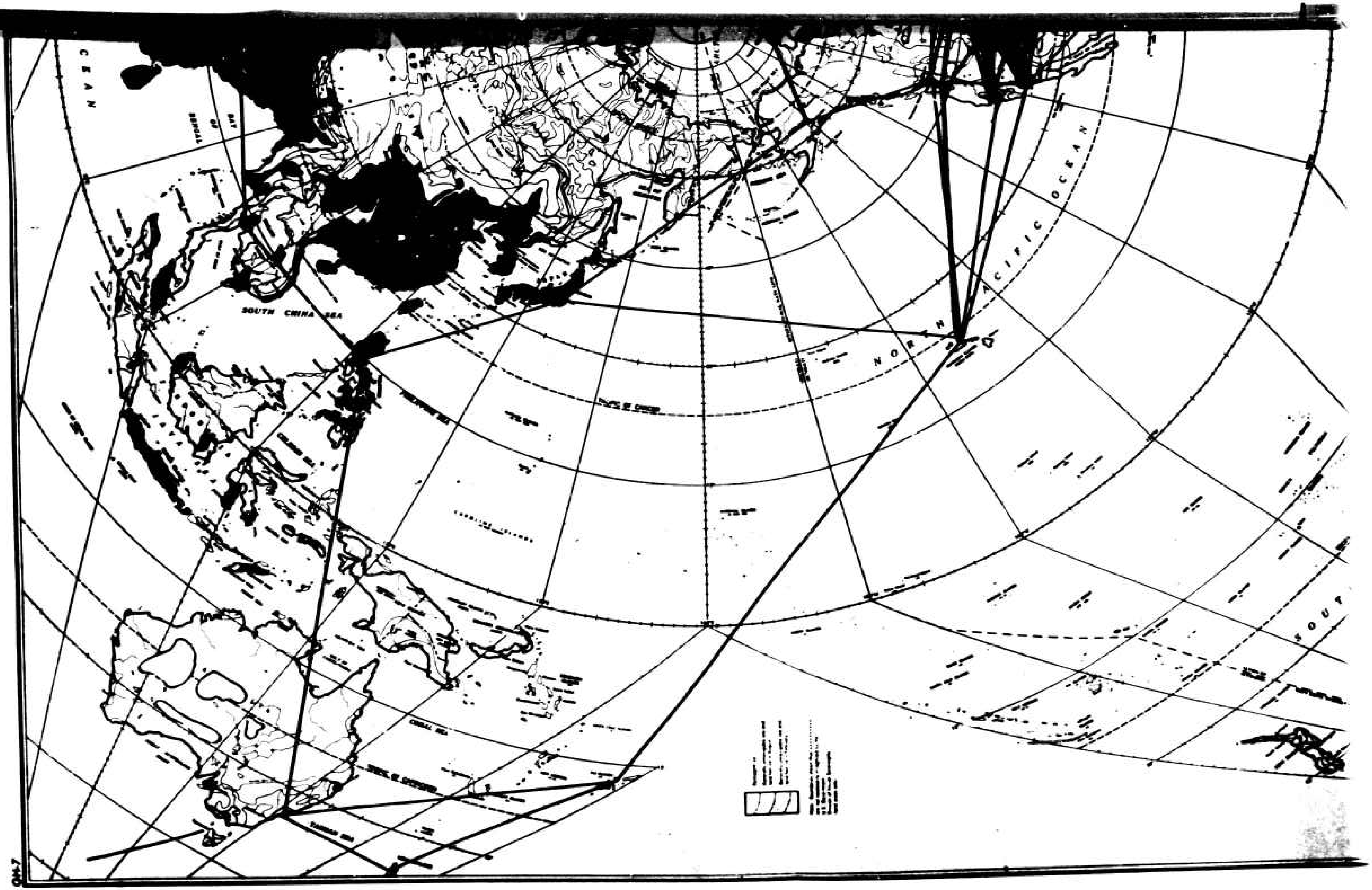

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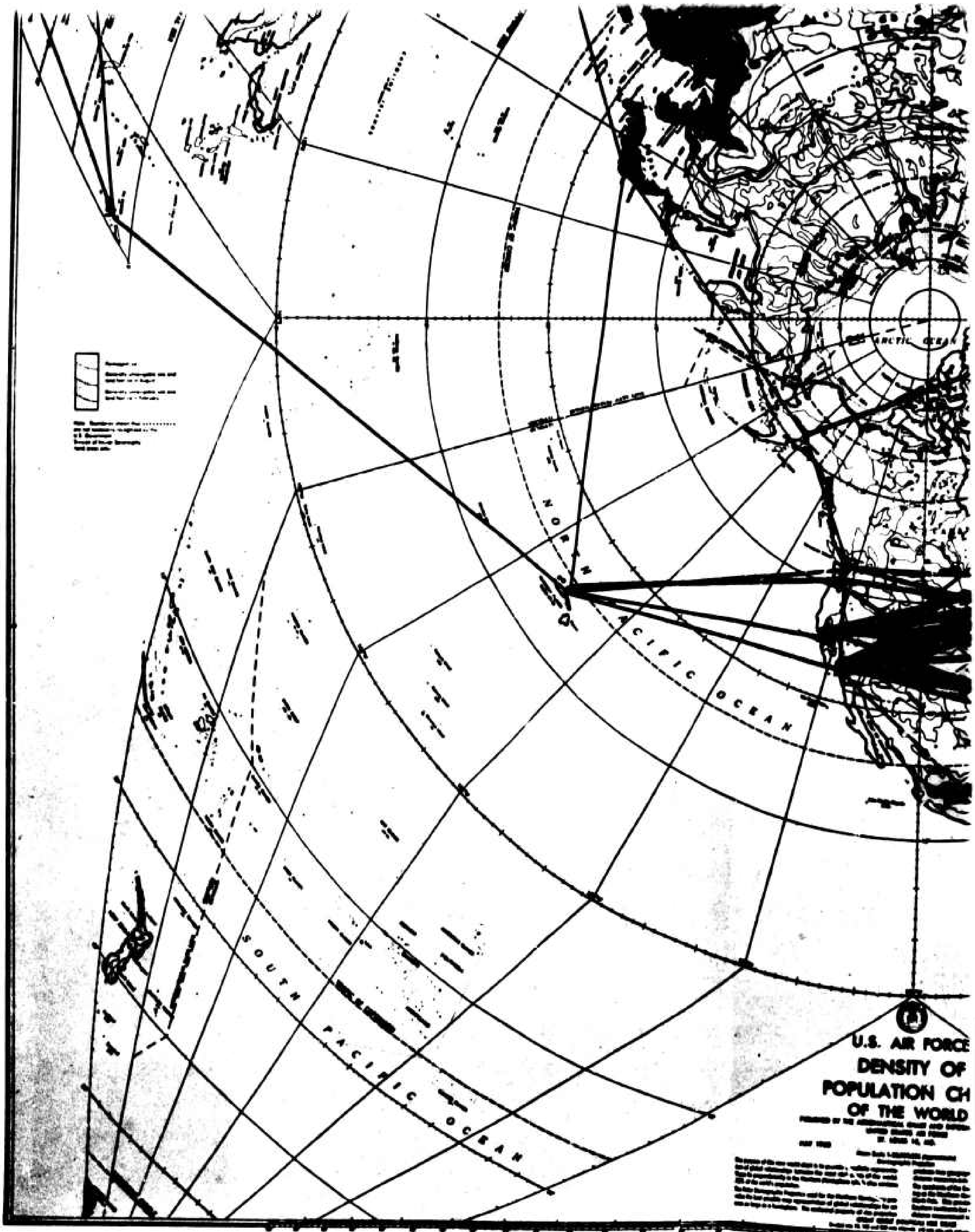

Figure A2.6. Case IV.

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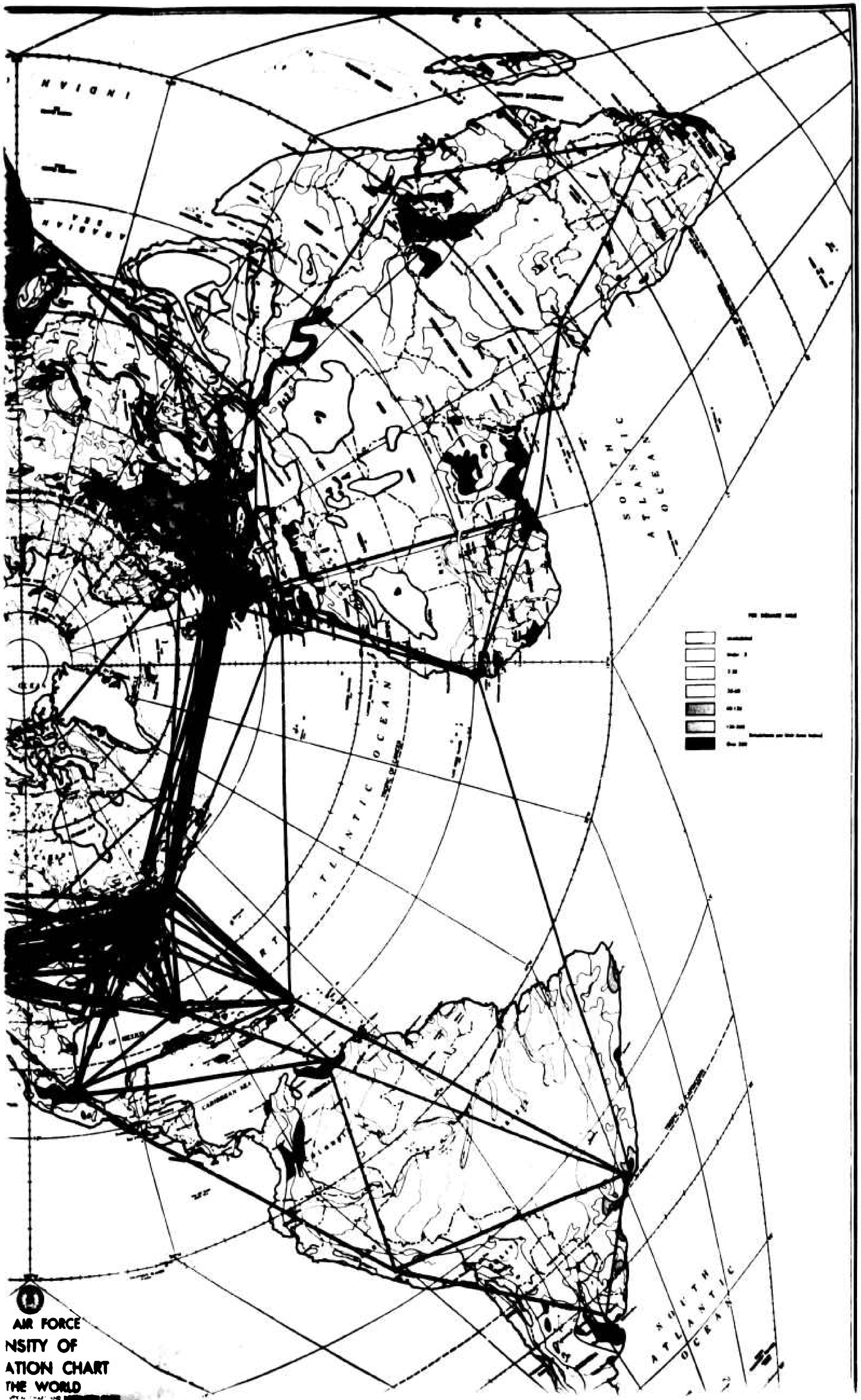
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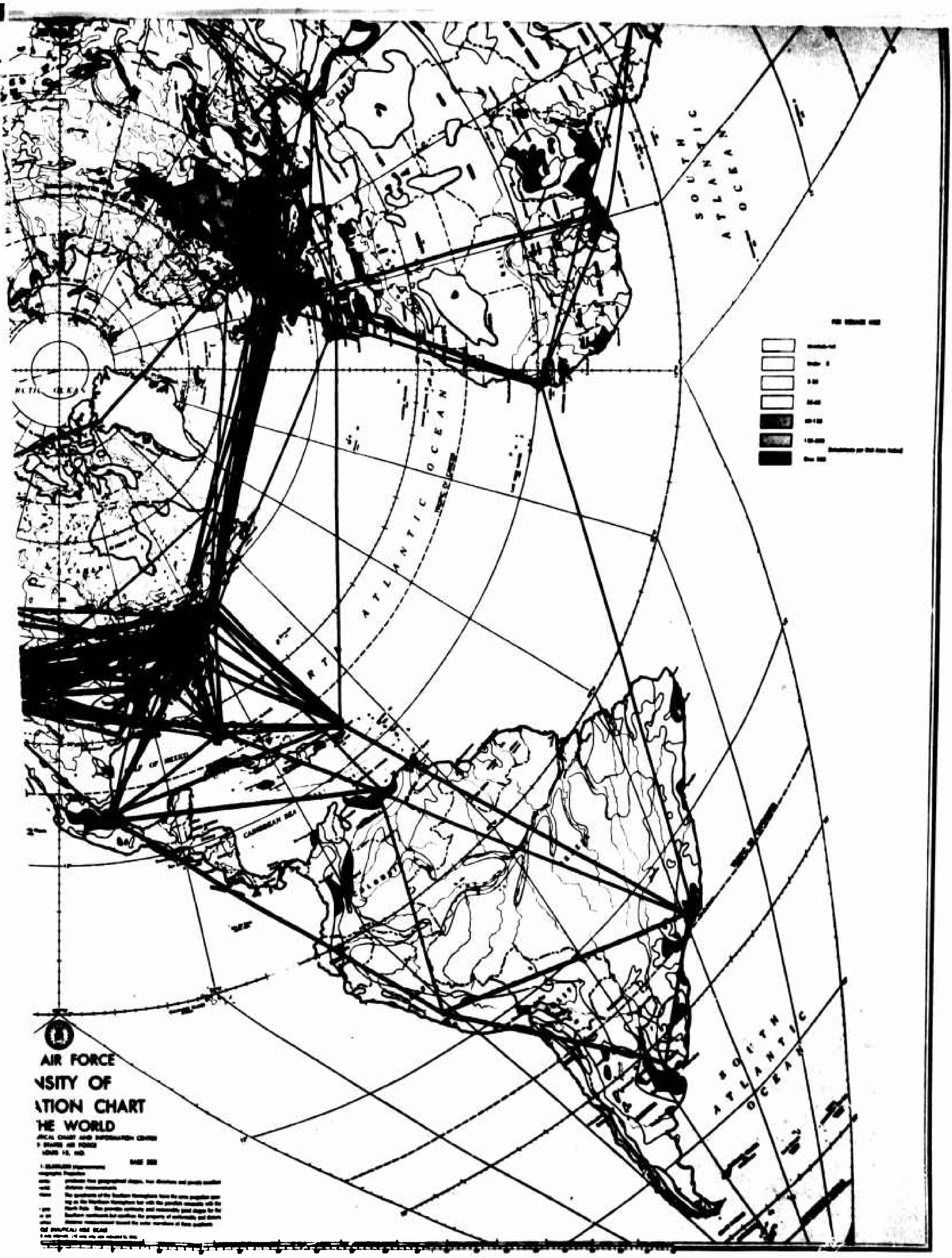

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Case V (Figure A2.7) shows the route system served by a supersonic transport as good as that in Case IV, but under the assumed condition that the effects of sonic boom are so severe as to result in restriction of the SST to over-water operations. This represents an extreme case for measuring the market impact of boom.

Total Aircraft Requirements

The number of aircraft required to serve a given city-pair depends on the block time, hours of daily utilization, and flight frequency offered. The aircraft requirements, in terms of the current subsonic jet, are first computed for Cases II, III, and IV above. These are then projected in accordance with the growth rates derived above to yield the corresponding requirements at any time in the forecast period, as shown in Table A2.5. The results for the current jet are projected as an equivalent required seat-mile capacity, and as though no other aircraft were available. To meet air transport needs in 1980, the airlines of the Free World must purchase a fleet of aircraft having a seat-mile capacity 3 to 5 times greater than that currently being operated. When these needs are translated into aircraft requirements in 1980 for Case IV, the 470 aircraft currently needed to serve the 154 city-pairs grows to 1900 aircraft of the same type, within a range of 1450 to 2480. It should be noted that our 1964 requirements are conservative. The International Air Transport Association has reported a Free World air fleet at year-end 1963 amounting to 637 four-engine jets. By year-end 1964, this fleet has probably grown to over 700 jets. In limiting our analysis to only 154 major city-pairs and using a growth rate based on total traffic rather than long-range traffic, we are undoubtedly understating the total requirement for long-range aircraft.

The corresponding seat-mile capacities expressed in terms of the Boeing SST are shown in Table A2.6. Note that a fleet of 160 supersonic transports (operating at overpressures of 2.0/1.5 pounds per square foot) would have been required to meet the needs for Case IV in the Summer of 1964. By 1980, however, a fleet of 500 to 860 aircraft would be required, with a base estimate of 660.

The corresponding seat-mile capacities expressed in terms of Concorde aircraft are shown in Table A2.7. Since the Concorde has a significantly lower productivity than the Boeing SST (as measured in annual seat-mile generating capacity), the number of Concordes required is greater.

The unusually large capacity of the commercial CX-HLS requires that it be operated only in the very dense traffic markets. A route analysis of the same 154 city-pairs was performed in much the same manner as for the aircraft above. An additional assumption was that the HLS would provide service only for those city-pairs capable of supporting 3 daily round trips at any given time in the forecast period. (In most markets, there are three competing airlines, each of which must offer the service.) The results are listed in Table A2.8.

Flight Equipment Choice

The major factors affecting demand for aircraft (see Figure A2.8) are as follows:

a. the response of air transport users to scheduling convenience, comfort, fare differentials, and trip-time differentials,

b. the policies and practices of competing airlines as they seek profits, return on investment, market share, prestige, or some combination of these objectives,

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Tokyo - Anchorage
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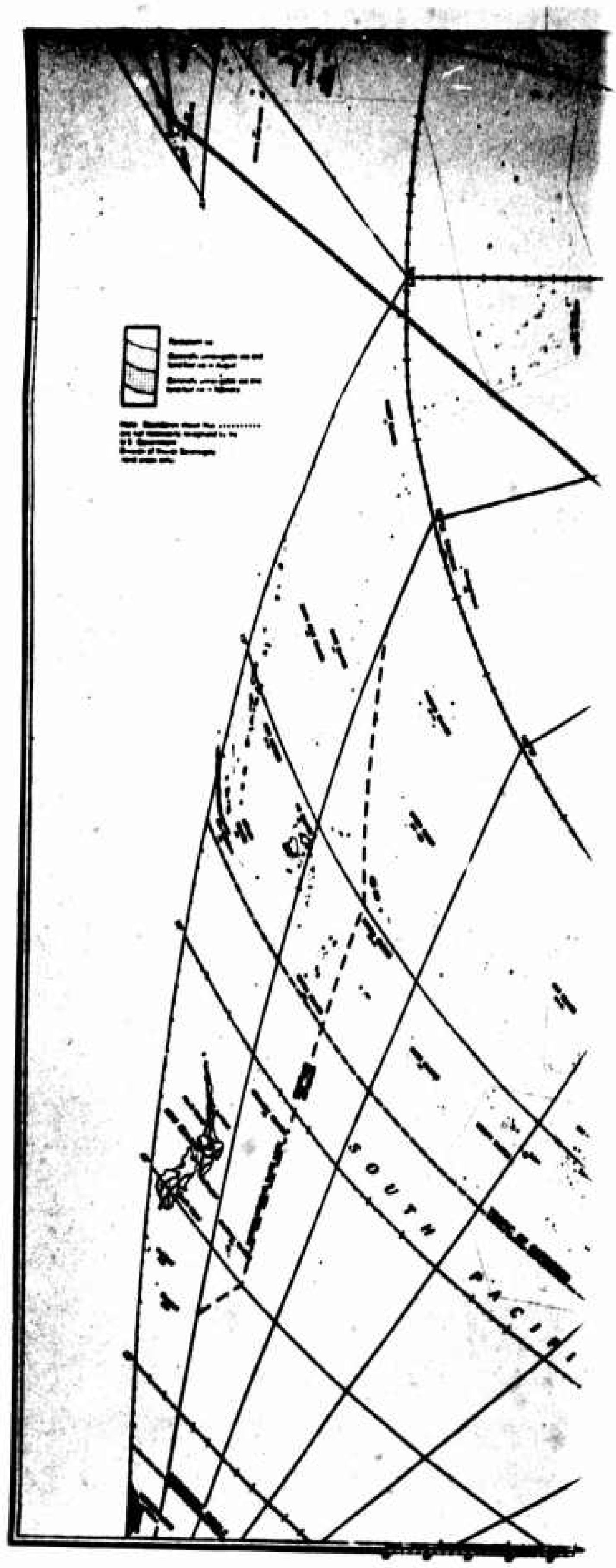

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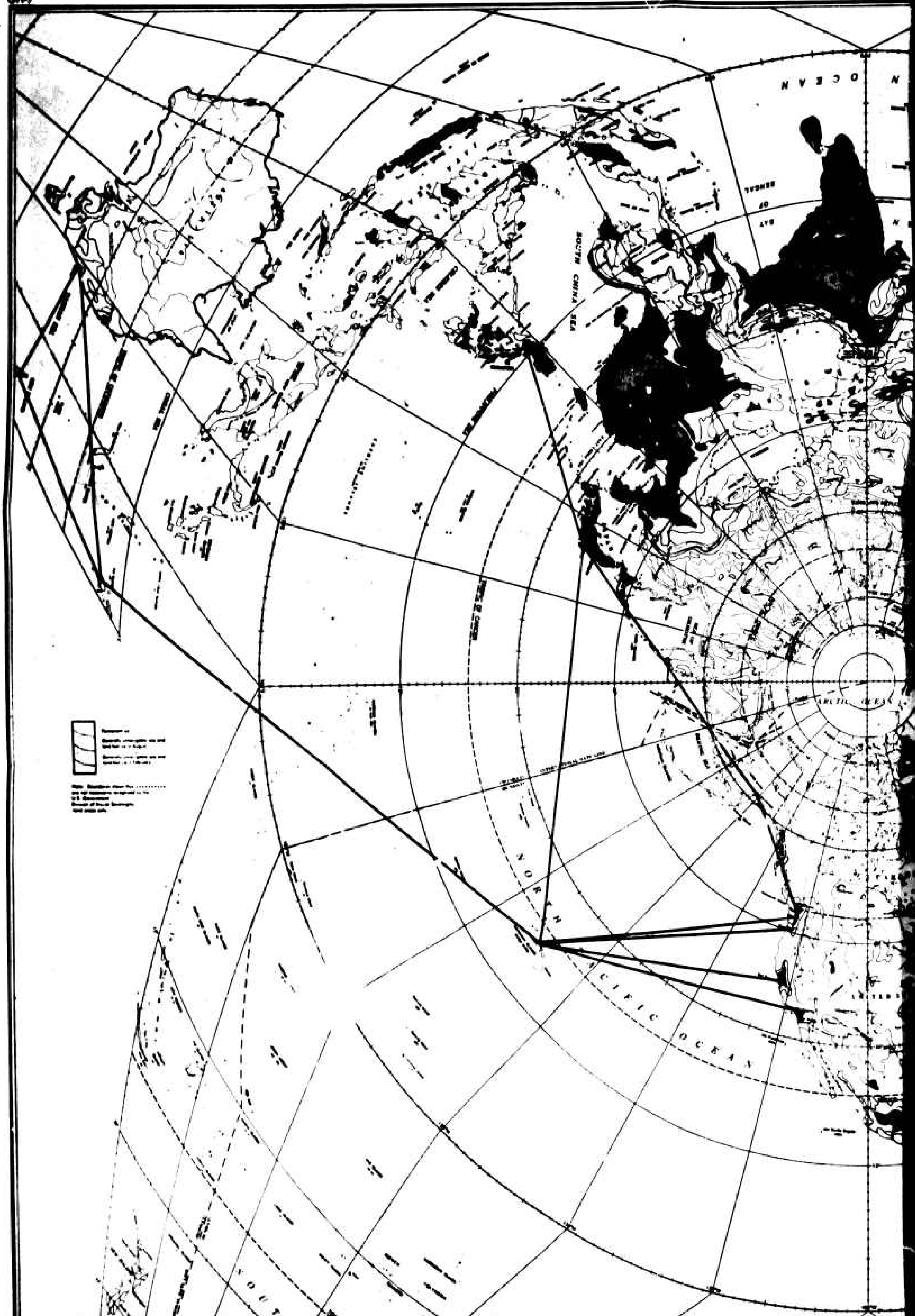


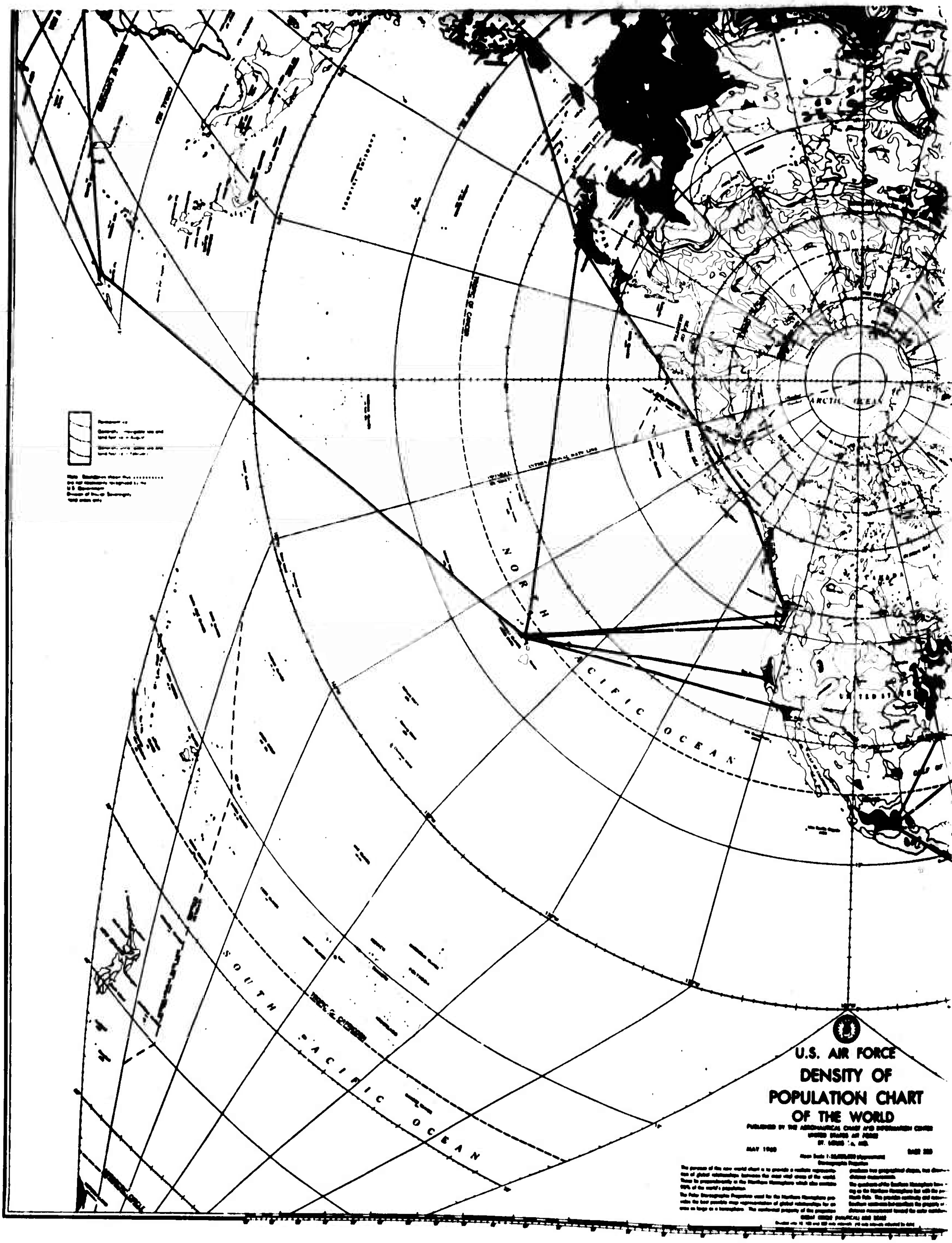
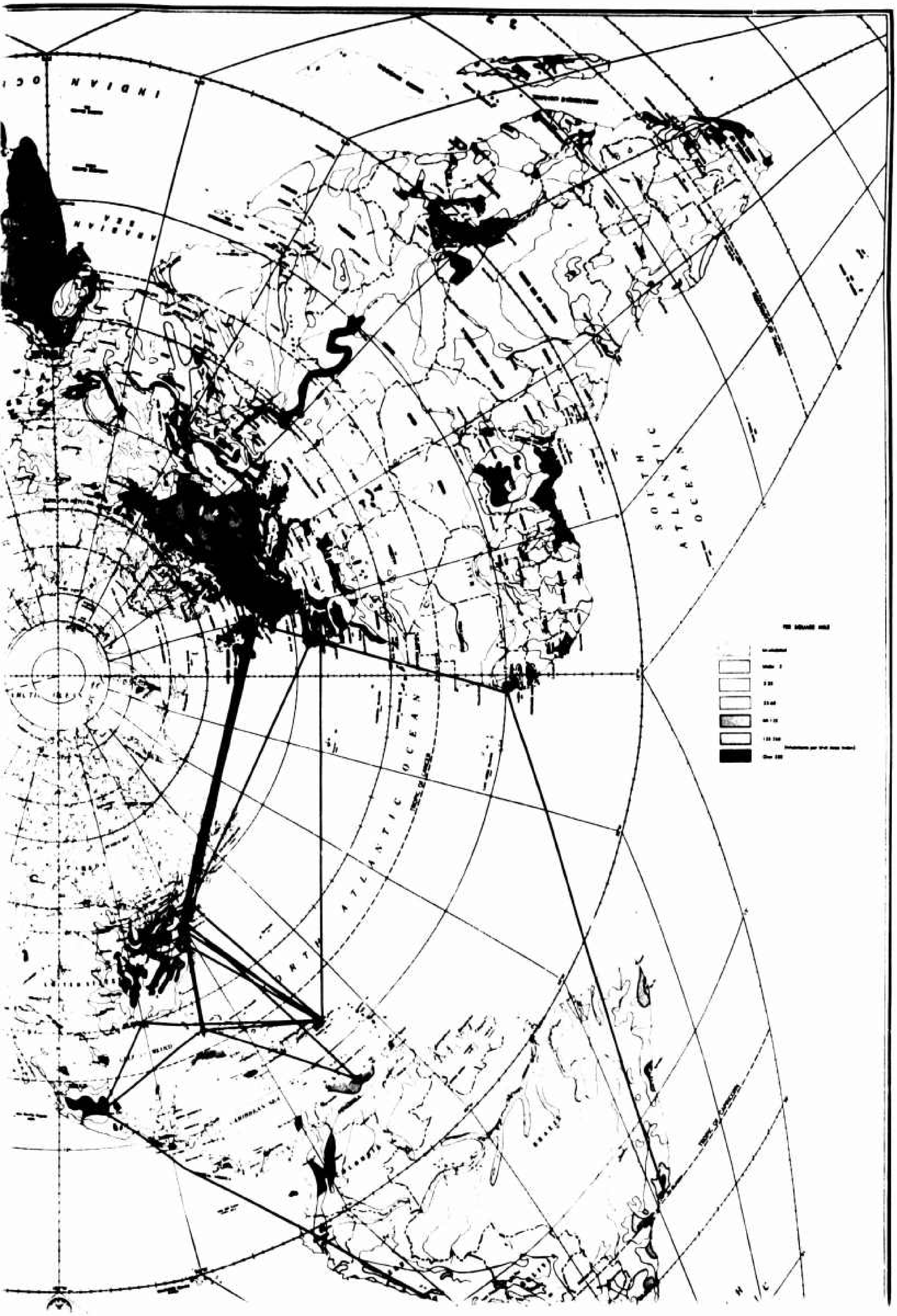


Figure A2.7. Case V.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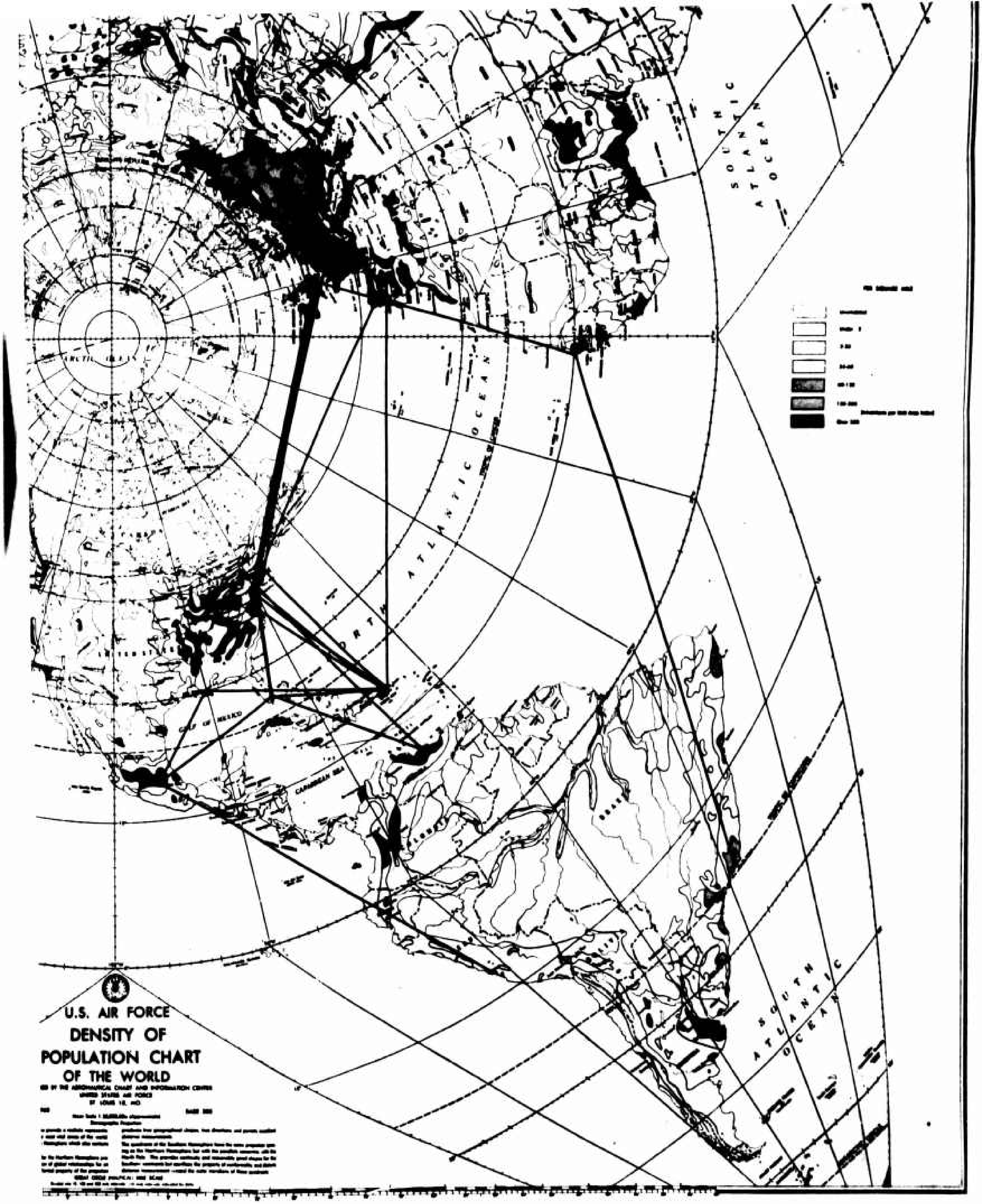
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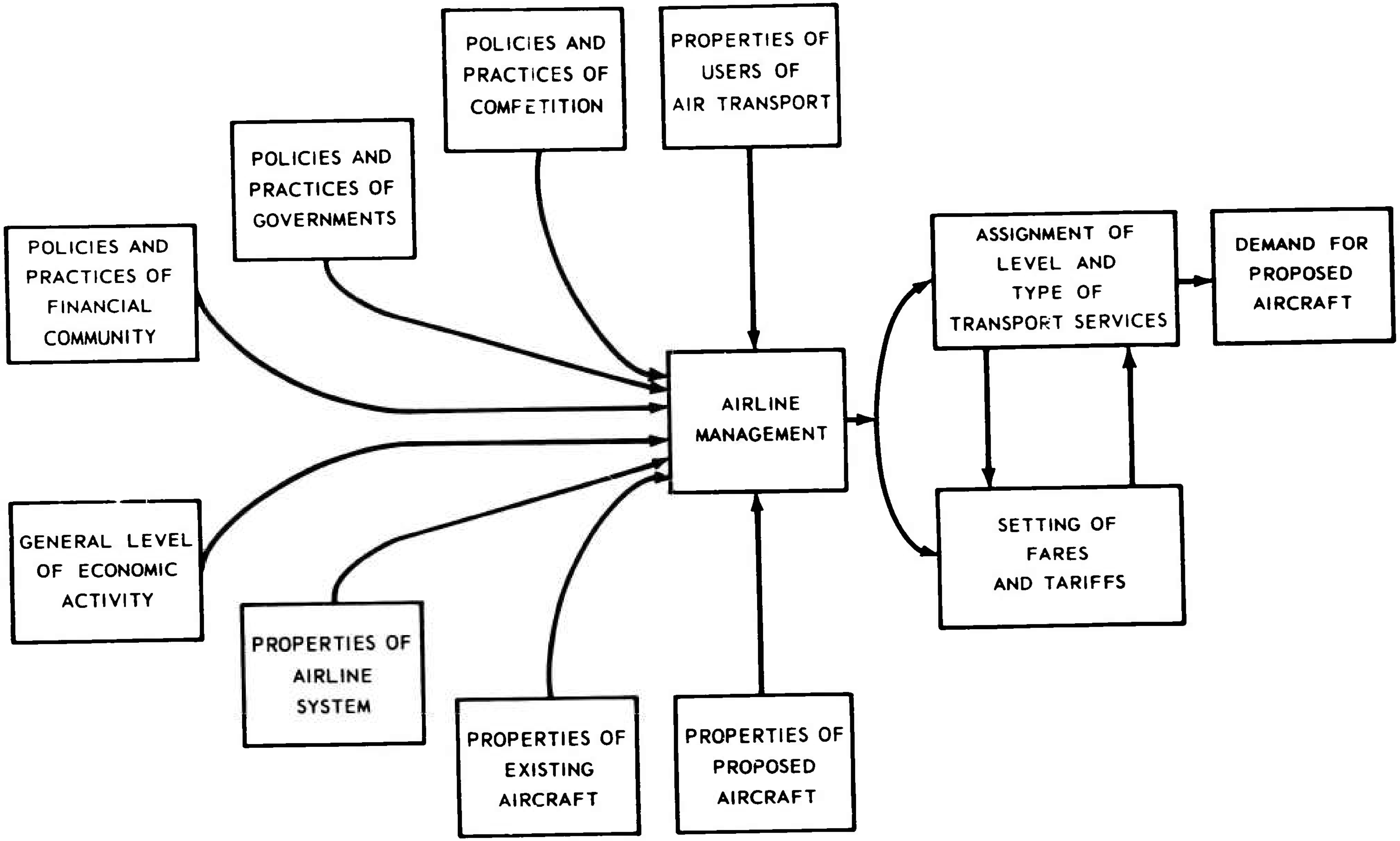

Figure A2.8. Factors affecting demand for proposed aircraft.

Table A2.5. Total Seat-Mile Capacity Required 1964-1990, Expressed in Terms of Boeing 707-320B Aircraft
(9 hours daily utilization)

Year	Relative market size	Case I	Case II	Case III	Case IV	Case V
			Low growth rate (6% avg.)			
1964	1.00	--	320	370	470	--
1972	1.85	--	590	680	860	--
[redacted]	3.10	--	1000	1140	1450	--
1990	5.33	--	1710	1950	2490	--
			Base growth rate (8% avg.)			
1964	1.00	--	320	370	470	--
1972	2.14	--	690	780	1000	--
[redacted]	4.07	--	1310	1490	1900	--
1990	7.97	--	2560	2920	3720	--
			High growth rate (10% avg.)			
1964	1.00	--	320	370	470	--
1972	2.46	--	790	900	1150	--
[redacted]	5.31	--	1700	1940	2480	--
1990	11.82	--	3800	4330	5520	--

Table A2.6. Total Seat-Mile Capacity Required 1964-1990, Expressed in Terms of Boeing 733-290 Aircraft
(9 hours daily utilization)

Year	Relative market size	Case I	Case II	Case III	Case IV	Case V
			Low growth rate (6% avg.)			
1964	1.00	28	110	120	160	50
1972	1.85	28	200	230	300	100
[redacted]	3.10	28	340	380	500	170
1990	5.33	28	580	660	860	290
			Base growth rate (8% avg.)			
1964	1.00	28	110	120	160	50
1972	2.14	28	230	260	350	120
[redacted]	4.07	28	440	500	660	220
1990	7.97	28	870	980	1280	430
			High growth rate (10% avg.)			
1964	1.00	28	110	120	160	50
1972	2.46	28	270	300	400	130
[redacted]	5.31	28	580	650	860	290
1990	11.82	28	1290	1450	1900	640

Table A2.6. Total Seat-Mile Capacity Required 1964-1990, Expressed in Terms of Boeing 733-290 Aircraft (9 hours daily utilization)

Year	Relative market size	Case I	Case II	Case III	Case IV	Case V
		Low growth rate (6% avg.)				
1964	1.00	28	110	120	160	50
1972	1.85	28	200	230	300	100
1980	3.10	28	340	380	500	170
1990	5.33	28	580	660	860	290
		Base growth rate (8% avg.)				
1964	1.00	28	110	120	160	50
1972	2.14	28	230	260	350	120
1980	4.07	28	440	500	660	220
1990	7.97	28	870	980	1280	430
		High growth rate (10% avg.)				
1964	1.00	28	110	120	160	50
1972	2.46	28	270	300	400	130
1980	5.31	28	580	650	860	290
1990	11.82	28	1290	1450	1900	640

Table A2.7. Total Seat-Mile Capacity Required 1964-1990, Expressed in Terms of Concorde Aircraft (9 hours daily utilization)

Year	Relative market size	Case I	Case II	Case III	Case IV	Case V
		Low growth rate (6% avg.)				
1964	1.00	67	260	300	[illegible]	140
1972	1.85	67	470	550	[illegible]	240
1980	3.10	67	[illegible]	[illegible]	[illegible]	[illegible]
1990	5.33	67	1370	1560	[illegible]	710
		Base growth rate (8% avg.)				
1964	1.00	67	260	300	[illegible]	140
1972	2.14	67	550	620	[illegible]	290
1980	4.07	67	1050	[illegible]	[illegible]	[illegible]
1990	7.97	67	2050	2340	[illegible]	1080
		High growth rate (10% avg.)				
1964	1.00	67	260	300	[illegible]	140
1972	2.46	67	630	720	[illegible]	330
1980	5.31	67	[illegible]	[illegible]	[illegible]	[illegible]
1990	11.82	67	3040	3460	[illegible]	1600

[redacted]

c. the properties of the route system operated by the airline (e.g., number and relative density of the various city-pairs served, route distances),

d. the properties of existing aircraft (e.g., costs, performance),

e. the properties of the proposed aircraft.

f. the policies and practices of governments in allocating routes, setting fares, subsidizing operations, and entering into agreements on air transport,

g. the policies and practices of the financial community with respect to flight equipment financing,

h. the general level of Free World economic activity.

With regard to the lattermost three factors, it is assumed that the current policies and practices of the financial community and of the various governments will persist into the future, and that the general level of Free World economic activity will continue to trend upward much as it has in the past decade.

Airline managements weigh these several factors, and then respond by determining the schedules of flight frequencies to be offered in each city-pair in its system, and the fares and tariffs desired. The various airlines together make up the transport system interconnecting many hundreds of city-pairs, each an individual market interacting with others and in which the relative significance of the several factors may vary. The diverse nature and great scope of air transport operations stem from a very large number of the decisions by managements, lenders and investors, and governments in meeting the needs of users.

Table A2.8. Total Seat-Mile Capacity and City-Pairs Available to the Commercial CX-HLS (9 hours daily utilization)

Year	Aircraft	City-pairs
1964	40	12
1972	140	31
1980	350	50
1990	810	84

These decisions are reflected in the cumulative percent distributions of long-range flight frequencies and aircraft versus distance, as shown in Figure A2.9. The curve of aircraft requirements lies above that for flight frequencies, because more aircraft are required to provide a given number of flight frequencies at the longer ranges than at the shorter. Thus, the cumulative total flight frequencies for the city-pairs separated by 2000 to 4000 miles represent 32 percent of the total flights market, while the aircraft requirement represents 43 percent of its corresponding total.

It is quite likely that each of the several aircraft considered here will find use in some Free World markets in the time period 1970-1990. The extent of such use will depend on the assessments made by the several airline managements of the first five factors listed above. Referring again to Figure A2.8, an airline management operates a system against competition using aircraft which hopefully yield as great returns on investment as possible. Such returns are possible only if the aircraft has favorable operating economics and is also attractive to the user. Although management seeks to optimize simultaneously over all these factors, only by careful balancing can the often conflicting requirements be met. For example, over a particular route segment, a management may operate an aircraft whose characteristics are suboptimal for that segment, but whose use

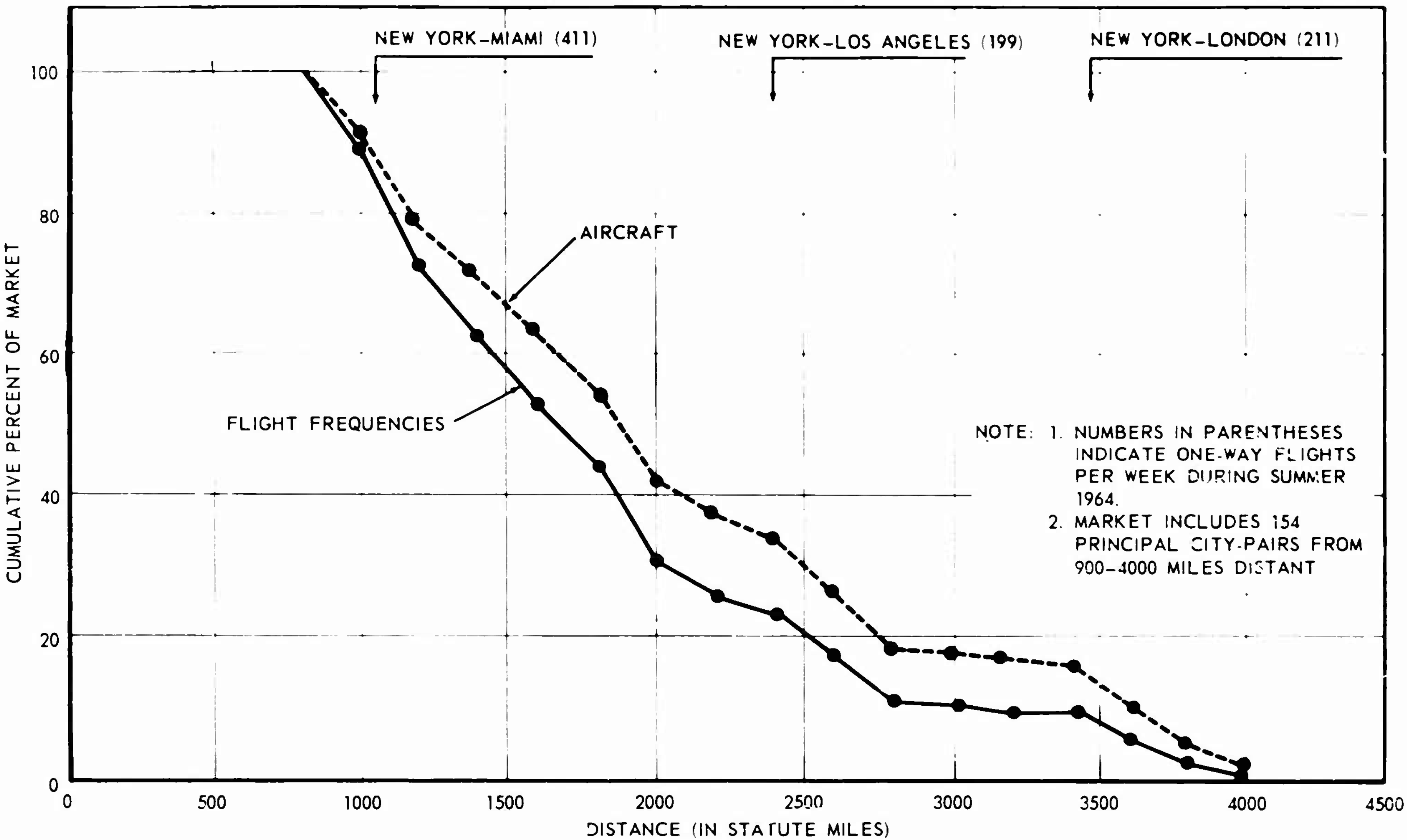

Figure A2.9. Cumulative percent of "Long-range Market" versus distance.

is dictated by broader system considerations or by the actions of competing airlines.

Rationale for Choice

Among the more important criteria used by airline managements in deciding whether to acquire new flight equipment are the following:

a. Total operating costs per passenger-mile versus the number of passengers, for each of several ranges.

b. Total operating costs and direct operating costs per seat-mile versus range.

c. Total operating costs and direct operating costs per aircraft-mile versus range.

Since operating costs are large compared to investment costs, they strongly influence management thinking. The first criterion combines information relating both to demand and costs. The second and third criteria, relating only to costs, are often used by managements in choosing between flight equipments—the former being more suited to markets of medium and heavy density; the latter, to markets of low density.

Let us consider first the choice between two aircraft, differing greatly in speed but moderately in seating capacity (e.g., the choice between the SST and the Boeing 707-320B). On the basis of their experience in the piston-jet transition, many airline managements believe that travelers may be willing to pay as much as 10 percent more for a faster service. With such a premium in fare possible, an airline management might then choose a faster aircraft, even one with 10 percent higher operating cost, if it believed the faster aircraft would attract travelers from the slower. So long as the two aircraft do not differ significantly in seating capacity, the airline management could maintain the high frequency of service which travelers apparently desire.

The rationale of choice among these aircraft is illustrated by Figure A2.10, showing both the total operating cost per seat-mile and the cumulative percent distribution of the aircraft market versus range. The curve of total operating cost per seat-mile versus range for a newly proposed aircraft design is first compared with the standard of performance. If a 10 percent fare differential appears possible, airline managements may purchase the faster and more attractive aircraft when its cost curve approaches reasonably close to that of standard aircraft. For all route segments greater in length than the range at which the SST cost curve is no more than 1.1 times the standard aircraft (here defined as the "displacement range"), airline managements would be expected to use the SST rather than the standard aircraft. Corresponding to any such displacement range, one may then determine the associated SST market share by reference to the curve shown below of cumulative percent distribution of the aircraft market. Because of competitive and system considerations, the displacement range will actually appear as a band about the indicated route distance.

Let us consider next the choice between two aircraft differing radically in seating capacity. On a seat-mile basis, the larger aircraft would generally have the lower costs, whether the smaller aircraft is of the same or greater speed. Given the lower costs, an airline management must then consider whether the density of any of its markets is such that the larger aircraft can provide a sufficient number of flight frequencies to be acceptable to the travelers. In many of the denser markets, travelers are now being served with large numbers of flights per day.

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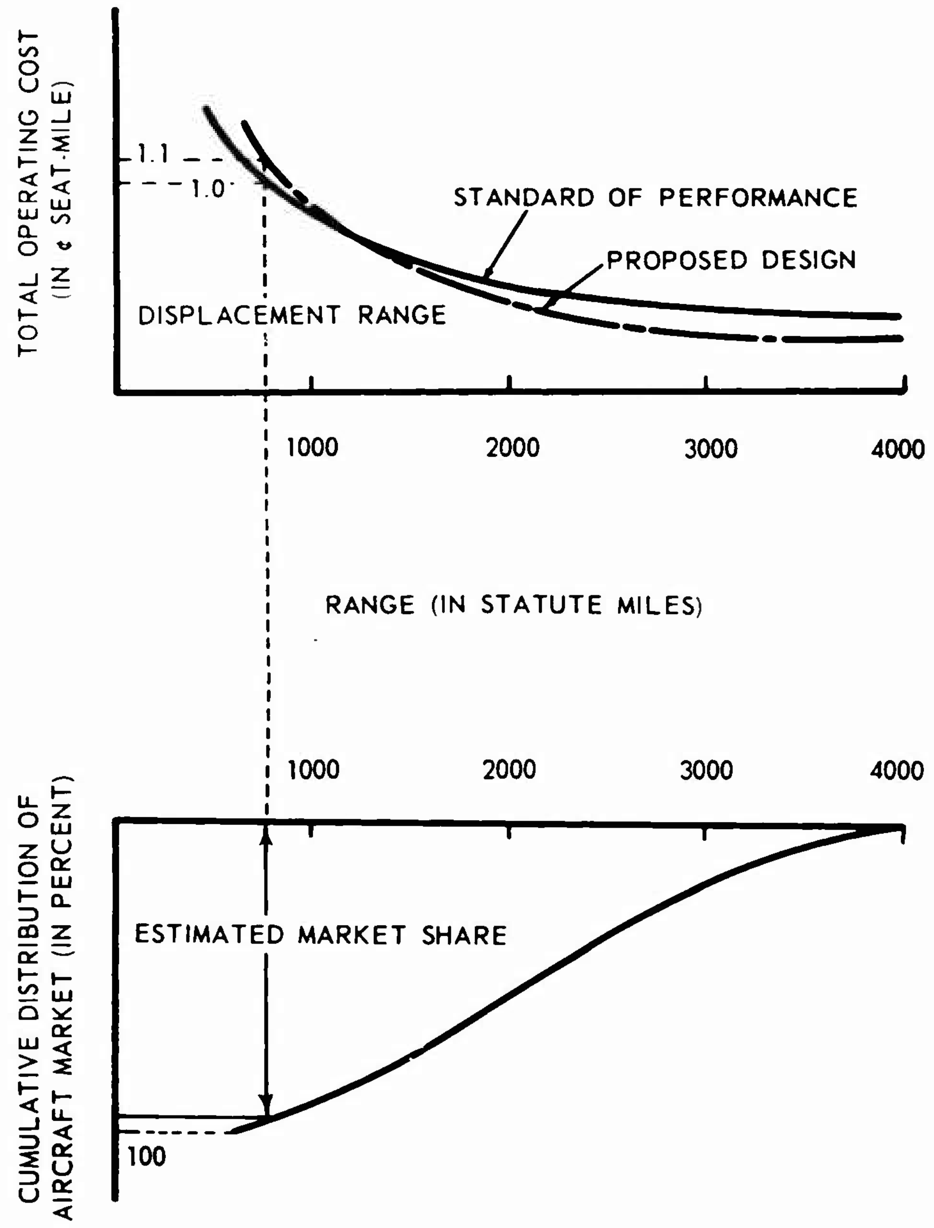

Figure A2.10. Determination of range of displacement.

For example, using June 1962 flight frequencies and average numbers of passengers per day, the San Francisco-Los Angeles market of 2140 passengers per day (on origin-destination basis) was served by 64 round-trip flights; the New York-Boston market of 3240 passengers per day was served by 78 round-trip flights.[1] In a competitive choice between the SST and the commercial CX-HLS, through its lower costs the latter aircraft must not only offset the adverse differential in trip time, but also the additional waiting time which would normally be associated with fewer flight frequencies per day.

Comparative Costs

A number of comparative cost relationships are shown below as a means for determining the kinds of markets in which the various aircraft may find use. In Figure A2.11 are shown the total operating costs per passenger-mile versus numbers of passengers. These are shown for domestic and international routes, and for ranges of 1,000, 2,000 and 3,000 statute miles, respectively. These cost relations suggest that the Concorde and the current subsonic jets may find use in low density markets; the growth subsonic jet and the SST, in the medium to high density markets; the commercial CX-HLS, only in the high density markets.

In Figure A2.12 are shown the total operating costs and direct operating costs per seat-mile for the several aircraft operating over domestic and international routes, respectively. The Concorde is seen to have a significantly higher seat-mile cost than all other aircraft; the CX-HLS, significantly lower. The costs of the current and growth

[1]"Handbook of Airline Statistics," 1963 edition, Civil Aeronautics Board, Part VI, Table 4a, p. 412.
"Official Airline Guide," June 1962.

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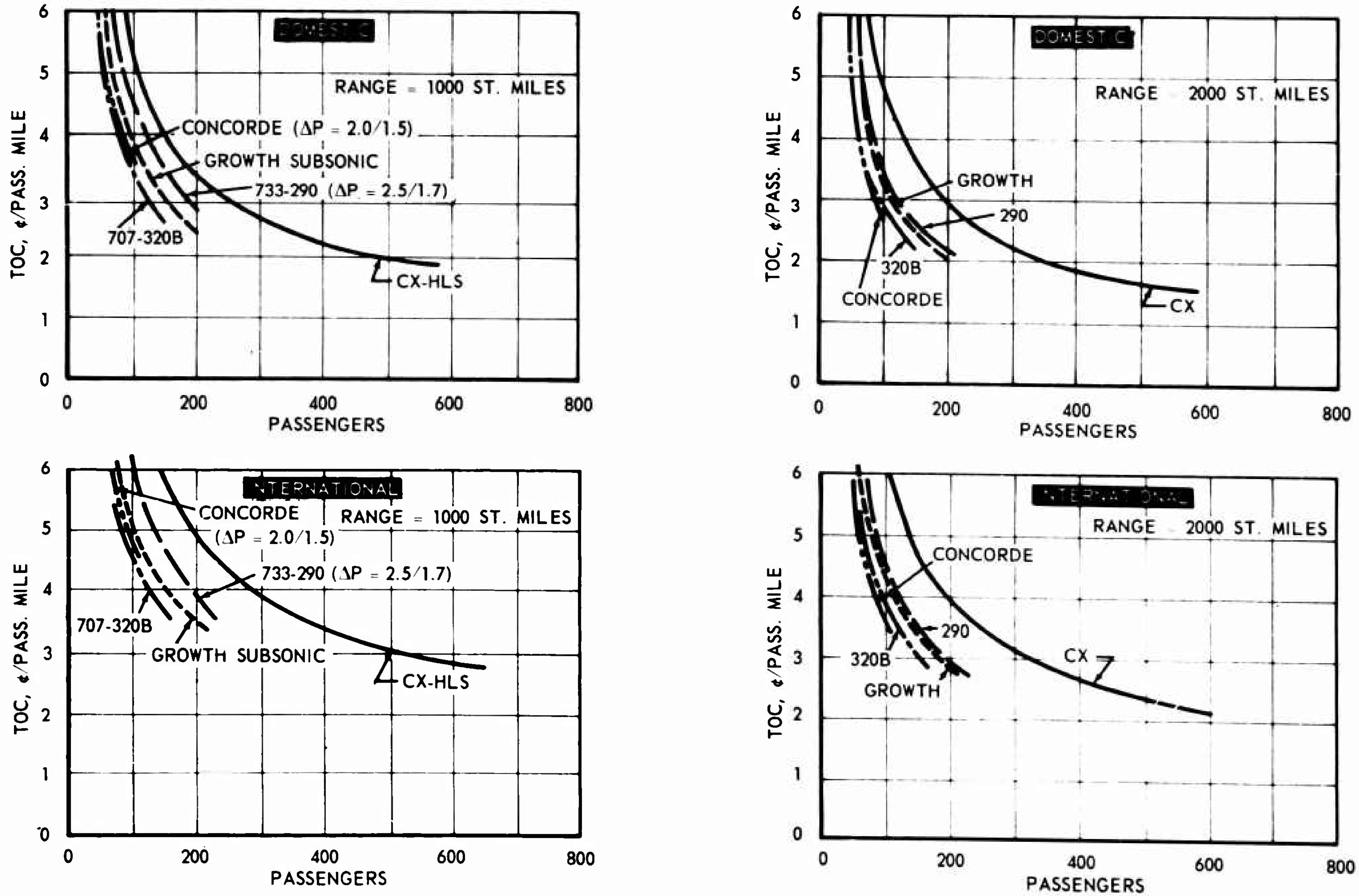

Figure A2.11. Total operating cost per passenger mile versus passengers (at 9 hrs. daily ut

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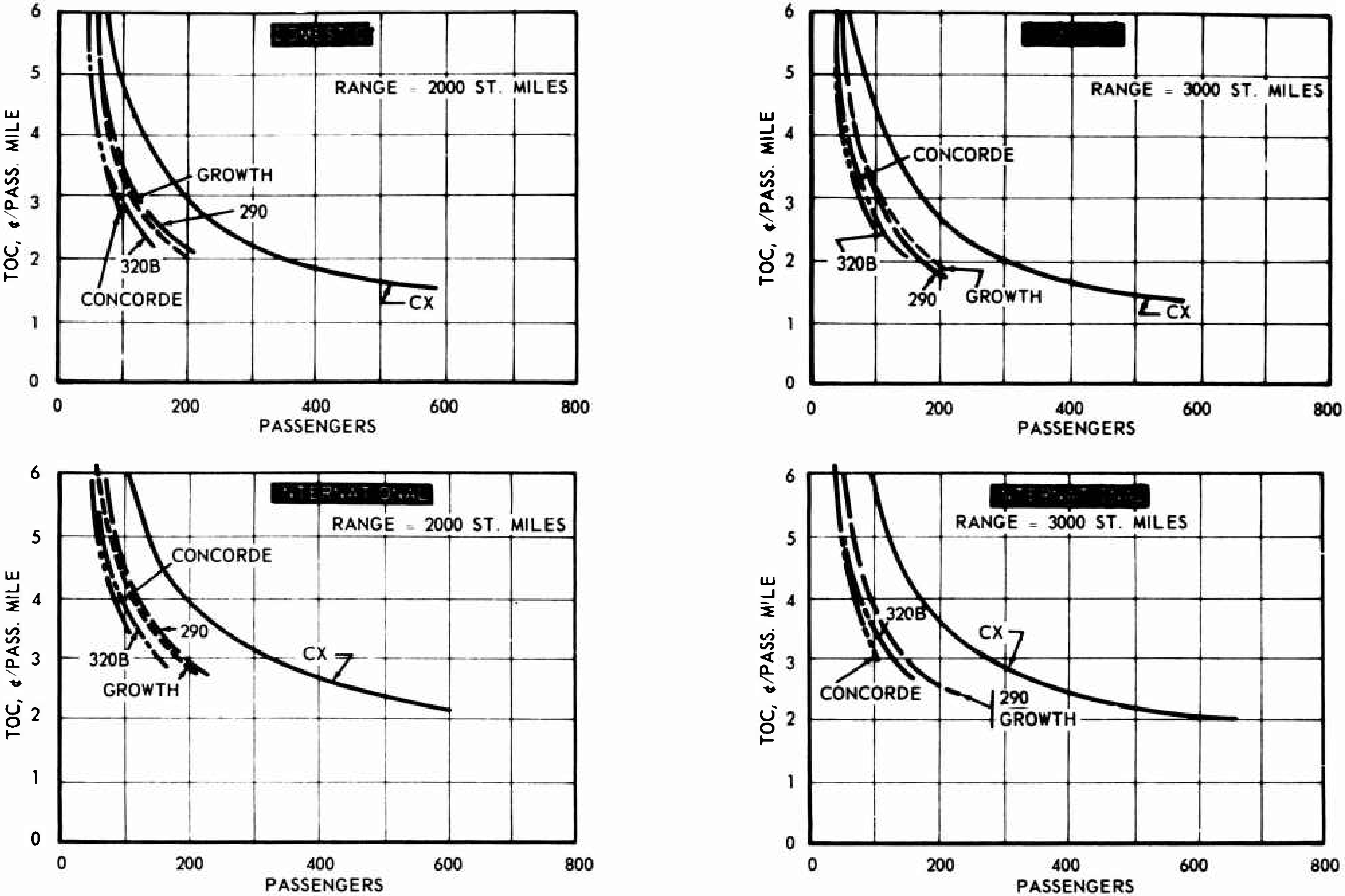

Figure A2.11. Total operating cost per passenger mile versus passengers (at 9 hrs. daily utilization).

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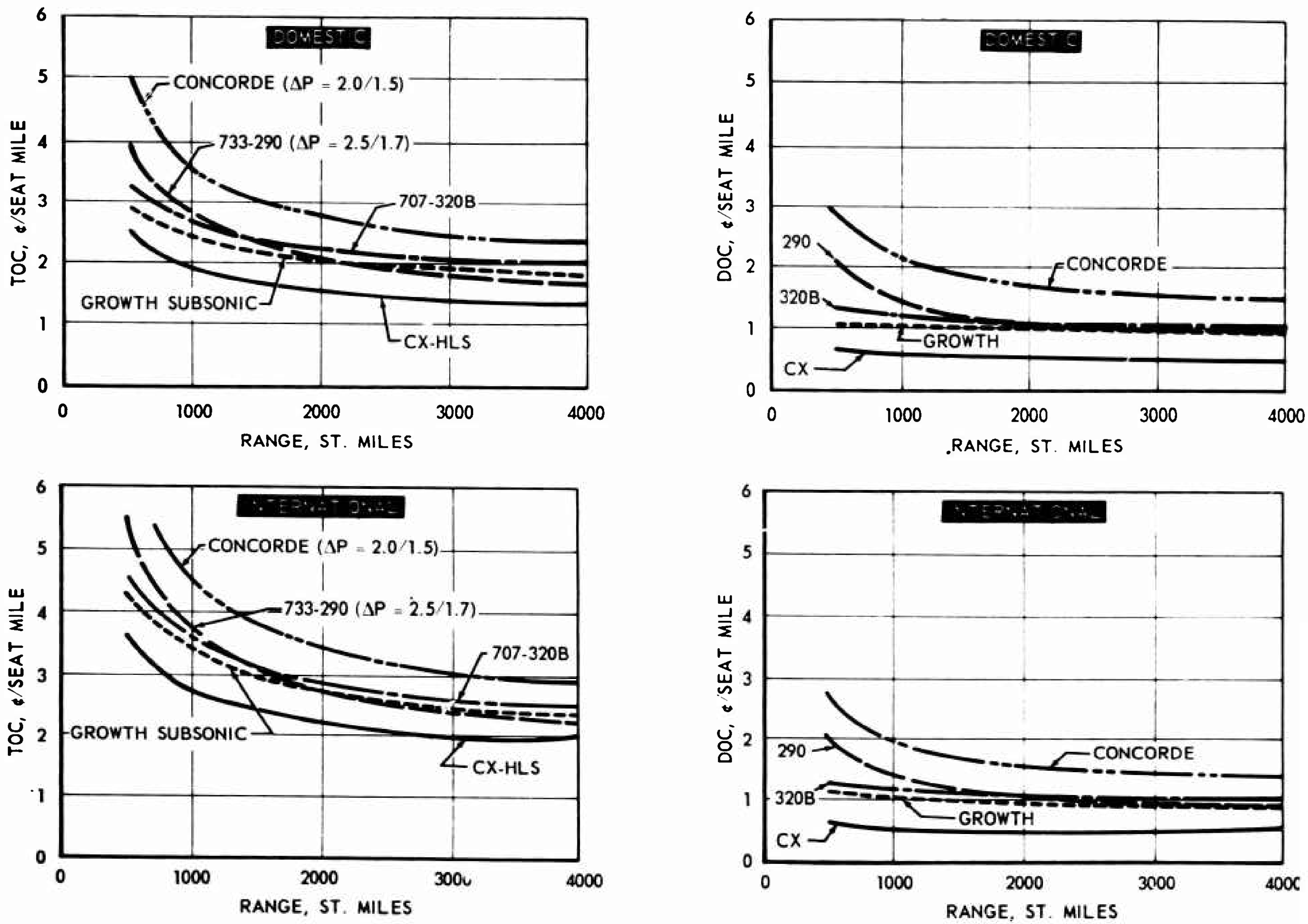

Figure A2.12. Cost per seat mile versus range (at 100% load factor and 9 hrs. daily utilization).

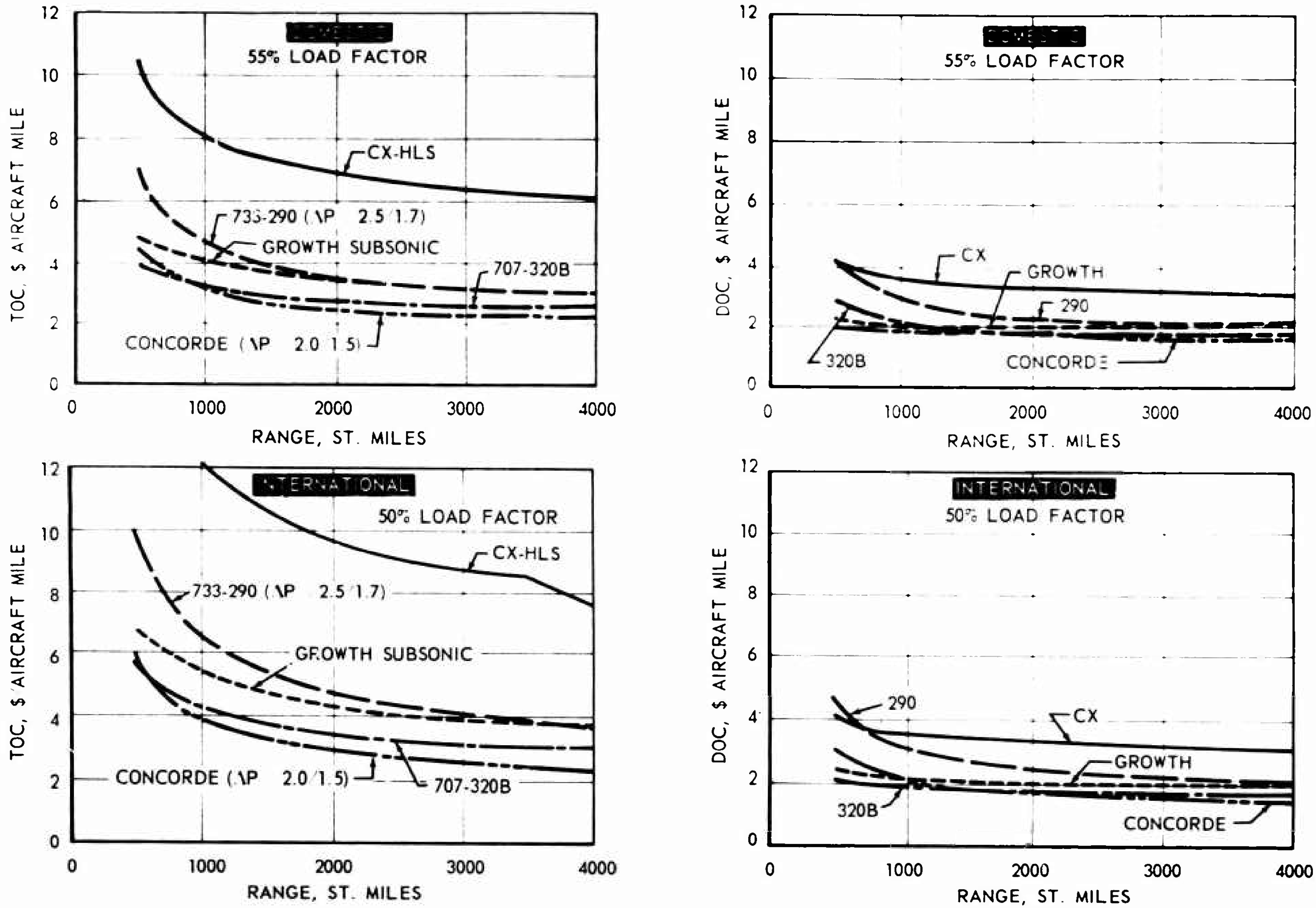

Figure A2.13. Cost per aircraft mile versus range (at 9 hrs. daily utilization).

subsonic jets, and the Boeing SST tend to cluster together. Insofar as total operating cost per seat-mile is concerned, the SST may displace the current subsonic jet at a range of about 800 miles; the growth subsonic, at a range of about 1000 miles. On the basis of direct operating costs per seat-mile, the SST may displace the current subsonic jet at a range of 1000 miles; the growth subsonic, at 1200 miles. On the basis of seat-mile cost, the commercial CX-HLS would displace all other aircraft, provided that the market density would support an aircraft of this great capacity.

In Figure A2.13 are shown the total operating costs and direct operating costs per aircraft-mile for the several aircraft operating over domestic and international routes, respectively. On an aircraft-mile basis, the commercial CX-HLS costs are significantly higher than those of all other aircraft; the Concorde costs, lower.

Leaving aside the broader system considerations and the possible actions of competing airlines, Figures A2.11 through A2.13 indicate that the Concorde may displace all other aircraft in markets of low density; the SST may displace all subsonics in medium and high density markets having route distances in excess of 1000 miles; the CX-HLS may prevail in the markets of very high density and relatively short route distance.

Summary

It is reasonably certain that the airlines of the Free World will be buying very large numbers of aircraft in the time period 1965 to 1980. Moreover, continuing growth of air transport at the base rate would result in an approximate doubling of seat-mile capacity requirements between 1980 and 1990.

On the basis of comparative costs to the airlines and attractiveness to the travelers, the market represented by the 154 principal city-pairs which could be available to the SST during the time period 1972-1980 is expected to be 660 aircraft, with a range between 500 and 860. This assumes that the commercial CX-HLS would not be offered on these same routes, and that the SST would prevail over the other aircraft. If the SST were restricted to overwater operations, the corresponding market estimate would be for 220 aircraft, with a range between 170 and 290.

If there were no supersonic aircraft and the commercial CX-HLS were used exclusively in the 50 city-pairs of greatest market density, there would be an expected requirement in 1980 for about 350 aircraft. The remaining 104 city-pairs might then be served by other subsonic aircraft.

A3. RANKING OF PROGRAM ALTERNATIVES

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A3. RANKING OF PROGRAM ALTERNATIVES

The purposes of this section are to explain briefly the rationale underlying the method of ranking the program alternatives, to indicate the sources of data and major assumptions, to present the principal results, and to examine their sensitivity to errors in estimation.

A3.1 ANALYTIC APPROACH

Each of the program alternatives may be represented by a stream of cash (costs and revenues) in time, flowing from the decision to proceed with prototype development until the last aircraft is retired from the fleets of the Free World. For purposes of analysis, the program cash flow may be divided into the respective flows for the manufacturing sector (airframe, engine, or both) and for the air transport sector (U.S. flag, foreign flag, or both). For each sector, the flows may be further subdivided by phase of program (development and production for the manufacturing sector; acquisition and operations for the air transport sector). In Figure A3.1 we see typical cash flows for the manufacturing and air transport sectors over the life cycle of the SST Program. All costs and benefits are recognized at the time incurred. For example, the costs of acquiring flight equipment are recognized at the time these costs are incurred; there is then no subsequent charge for depreciation of this equipment. In addition to the flows for these two sectors, to the extent that the Government may be directly involved, there would be cash flows for the public sector.

In ranking alternatives, we follow the prudent investor who seeks always to maximize his present worth. In computing present worth, he discounts at his cost of capital the streams of expected costs and benefits for each alternative. Provided his alternatives are not strongly interdependent (and hence require the choice of a combination of programs), he then chooses that program whose cash flows yield the greatest present worth. Excepting certain unusual patterns of cash flow (not the case here), the investor might equivalently rank each alternative with respect to its internal rate of return (i.e., the interest rate which will equate the present worth of all cash receipts with the present worth of all cash expenditures). In this report, we shall show the ranking on the basis of both criteria:

a. Present worth of the net cash stream at some specified costs of capital. A number of rates will be used which may vary among the manufacturing sector, the air transport sector, and the Government sector. The rankings on this basis will be given in Part II.

b. Internal rate of return.

The present worth of, or rate of return for, an aircraft program may be computed <u>without</u> making any prior estimate of the market actually available to that aircraft. For example, we may ask:

"If a market success of 200 aircraft were achieved by the Boeing 733-290 under certain specified conditions, what then would be the associated rate of return?"

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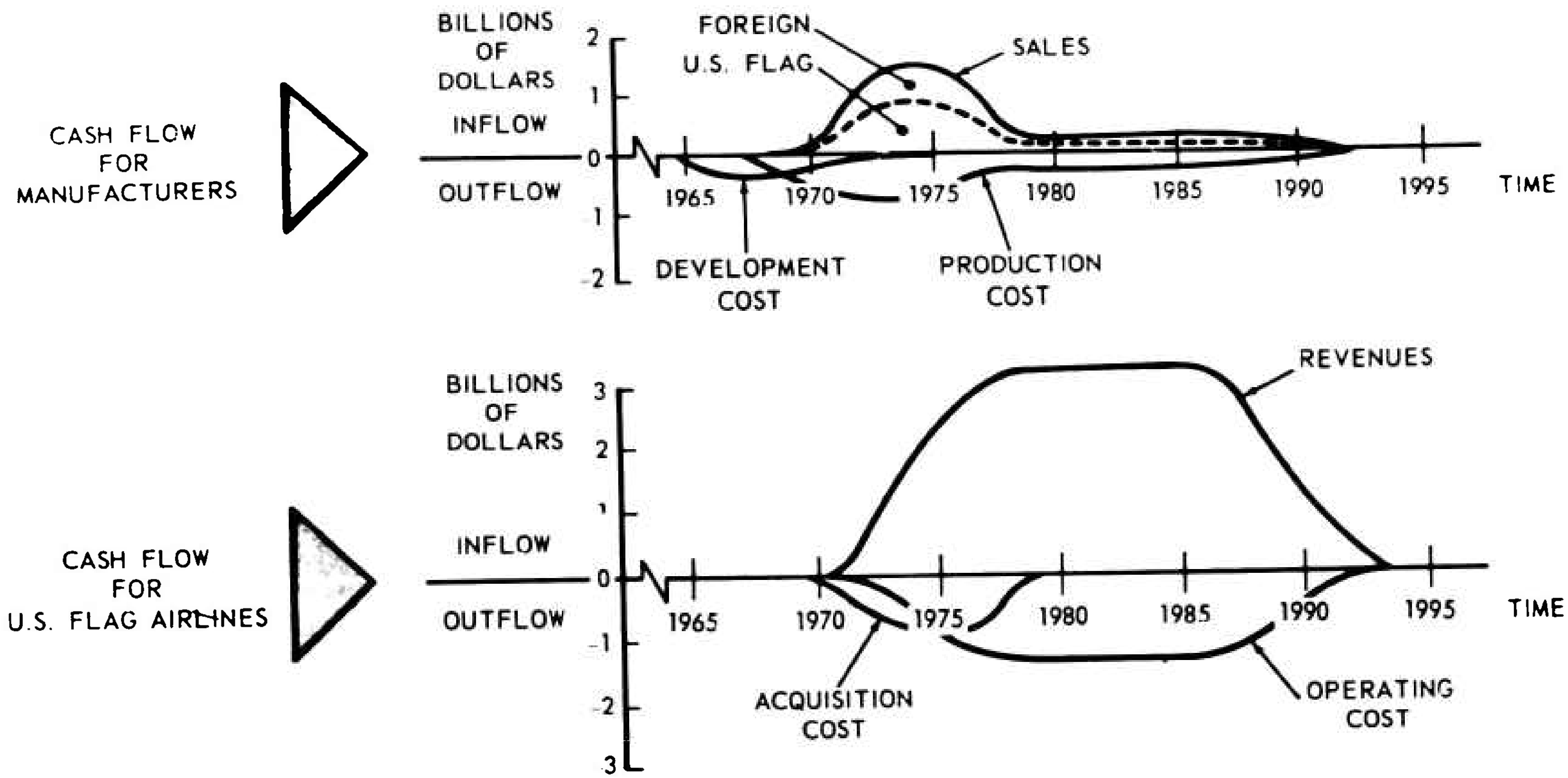

Figure A3.1. Typical cash flows over life cycle of SST Project.

For each aircraft alternative, the same question may be repeated for a range of market success from 50 to 600 aircraft, thus yielding a corresponding range for the rates of return which may be achieved.

Figure A3.2 illustrates the manner in which the ranking of alternative aircraft will be presented. For each aircraft there is a curve which indicates the degree of market success required (in terms of numbers of aircraft) to achieve any specified rate of return. As shown in this example, SST_A represents a better program choice than SST_B. Thus, at a desired rate of return (before interest and taxes) of 25 percent, SST_A requires a market success of only 175 aircraft; SST_B, 500 aircraft. Alternatively, if a market of 300 aircraft is in prospect, then SST_A will yield a greater return than SST_B. Also shown on this figure are two lines: interest rate and market ceiling. The region below the "market ceiling" and to the right of the "interest rate" is that within which economically profitable program choices are feasible.

A3.2 PRINCIPAL ASSUMPTIONS

Consider now the approach taken to the systematic sketching of a number of possible program outcomes. With the cooperation of Boeing and Lockheed, a set of ground rules were devised for the submission of SST data for the cost-benefit analysis. These ground rules provided the scenarios for eight SST program outcomes: two derived from choices with respect to program pace, combined with four possible degrees of market success. The alternatives for pace assume first in-service operation in 1972 or in 1974. The four degrees of market success assume the ultimate sale of either 50, 200, 400 or 600 SST aircraft—all of one model. The manufacturers were also asked to indicate separately their estimates of the incremental costs for development and production of a growth model SST. The ground rules provided for the generating of cash flows for development, production and sales in accordance with the eight specified outcomes. Profits and sales were computed in accordance with the manufacturers' customary practice on two bases: assuming zero amortization or 100 percent amortization of development costs.

Analogous ground rules were developed in cooperation with Boeing, Lockheed, and Douglas for the submission of CX-HLS data for the cost-benefit analysis. The basic assumptions provided for the commercialization of this aircraft following the production of 100 military aircraft, with three degrees of market success: 50, 100, or 200 commercial aircraft produced.

As indicated earlier, this analysis has been designed to permit the evaluation of a number of aircraft types under a variety of assumptions. To this end, contracts were let under the monitorship of the Department of Defense to Planning Research Corporation (PRC) and Operations Research, Incorporated (ORI) to provide estimating equations for the costs of development, production and operations. These equations permit the computing of various elements of cost (e.g., engine production cost, crew costs, airframe maintenance labor) as a function of the major physical and operational characteristics of the aircraft and of airline systems. By varying these characteristics (within the limits of equation applicability), the related impact on costs can be estimated. Although the major effort in this task was performed by the two contractors, an intramural effort on airline operating costs was undertaken and integrated, where appropriate, with the work of the contractors. Parallel and independent efforts by the contractors were considered essential because of the great uncertainties in estimating future costs for aircraft involving major technological

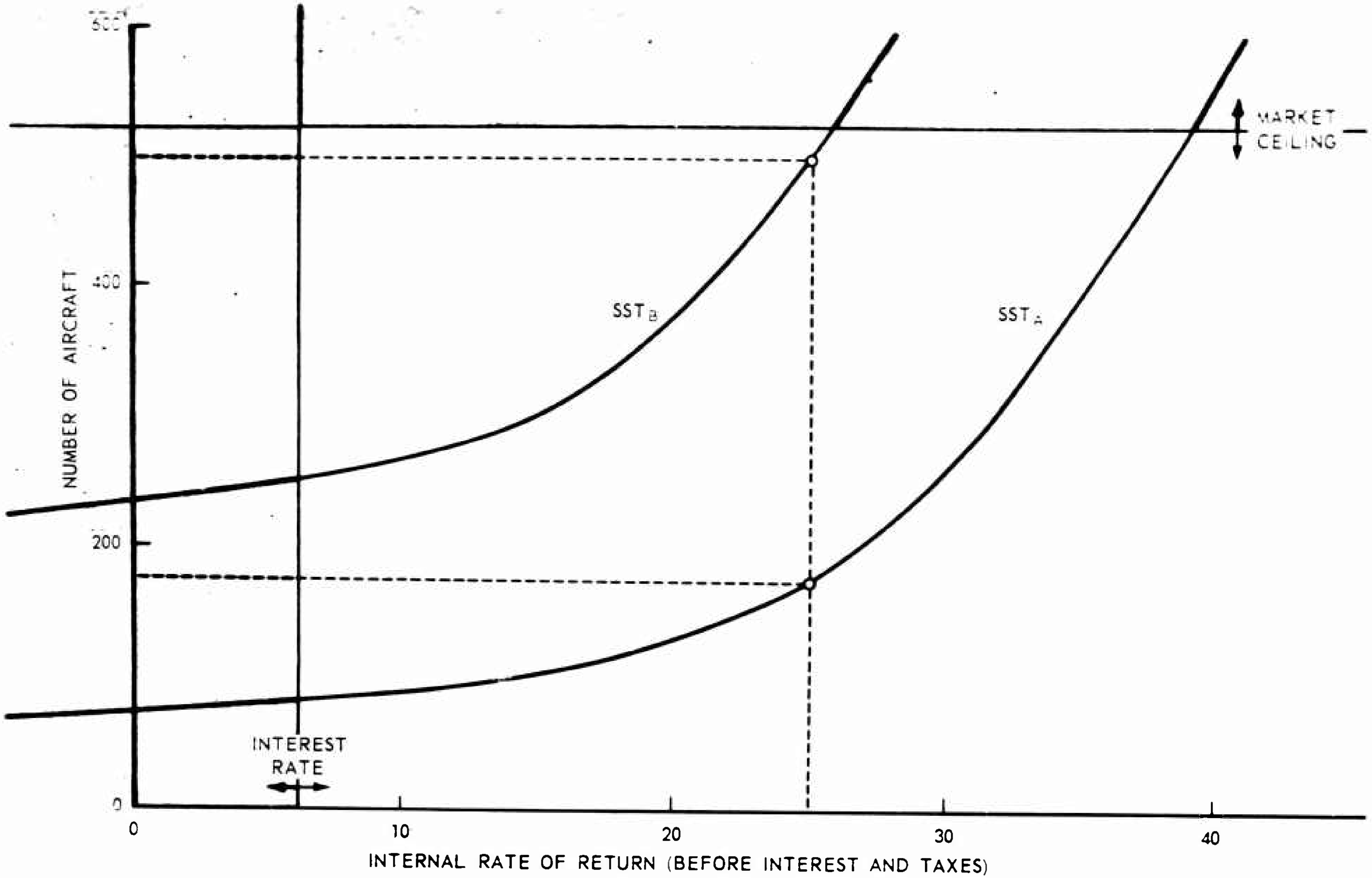

Figure A3.2. Market success required for a given rate of return.

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advances. Estimates for SST costs are therefore available from four expert groups (the manufacturer, the FAA-NASA-DOD evaluation team, PRC, and ORI), which should increase our confidence that the resulting range of expected cost is reasonable. The FAA data are treated as the nominal throughout the study. For each of the other aircraft under consideration, we have three estimates (the manufacturer, PRC, and ORI).

The two sets of data (the manufacturers and the FAA-validated data) and four sets of cost estimating relations may be combined to yield a variety of cost data inputs to the analysis. Figure A3.3 shows the inputs used for the analysis of the Boeing and Lockheed SST designs: manufacturers' data are shown at the left; the four cost data inputs used in the cost-benefit analysis are shown at the right.

Figure A3.4 shows the corresponding cost-data inputs used in the analysis of the Boeing 707-320B, the growth subsonic jet, and the Concorde. Again, the manufacturers' data are shown at the left; the three cost data inputs, at the right. For these aircraft, we are concerned only with the cash flows for the air transport sector. The Boeing 707-320B has been operational for almost three years, hence it was possible to check the manufacturers' data by discussions with the airlines. Although the growth subsonics are not expected to be delivered until 1967, they so closely resemble the Boeing 707-320B and Douglas DC-8 that the manufacturers' data could also be checked by discussions with the airlines. What meager data are available on the Concorde have been reviewed with NASA and the airlines to assure that the values used are realistic. These are expected to show the Concorde in a more optimistic light than it probably merits.

Figure A3.5 shows the corresponding cost-data inputs used in the analysis of the CX-HLS. Again we have three sets of estimates of development, production, and operating cost for each of the designs submitted by the several manufacturers.

A3.3 RESULTS OF COST-BENEFIT ANALYSES

In evaluating the results given below, one should attach more credence to the relative ranking of alternatives than to the absolute values shown. Aircraft with small differences in rate of return should be regarded as essentially equivalent choices for investment alternatives.

Table A3.1 lists the assumed nominal conditions for determining the cash flows associated with operation of the several aircraft types. Various numbers of each type are deployed over the 154 SST-potential routes (corresponding to Case IV in Section A2 above) in accordance with the production schedules specified in the cost-benefit ground rules. The rates of return on the resulting program cash flows (before interest and taxes) are then computed.

Figure A3.6 shows the comparative market success required for a given internal rate of return[1] to the manufacturers and the U.S. flag carriers, separately. Under the nominal conditions, the SST yields returns ranging from -11 to 29 percent to the manufacturer as market success increases from 50 to 600 aircraft; the commercial CX-HLS returns 37 to 87 percent on 50 to 200 aircraft, respectively. The corresponding returns to the U.S. carriers range from

[1]For comparative purposes, average returns on investment to manufacturers (before interest and taxes) range from 20 to 40 percent, with the aircraft manufacturers at the lower end of the range; returns to the airlines, 15 to 20 percent on the system, and much higher on the better routes.

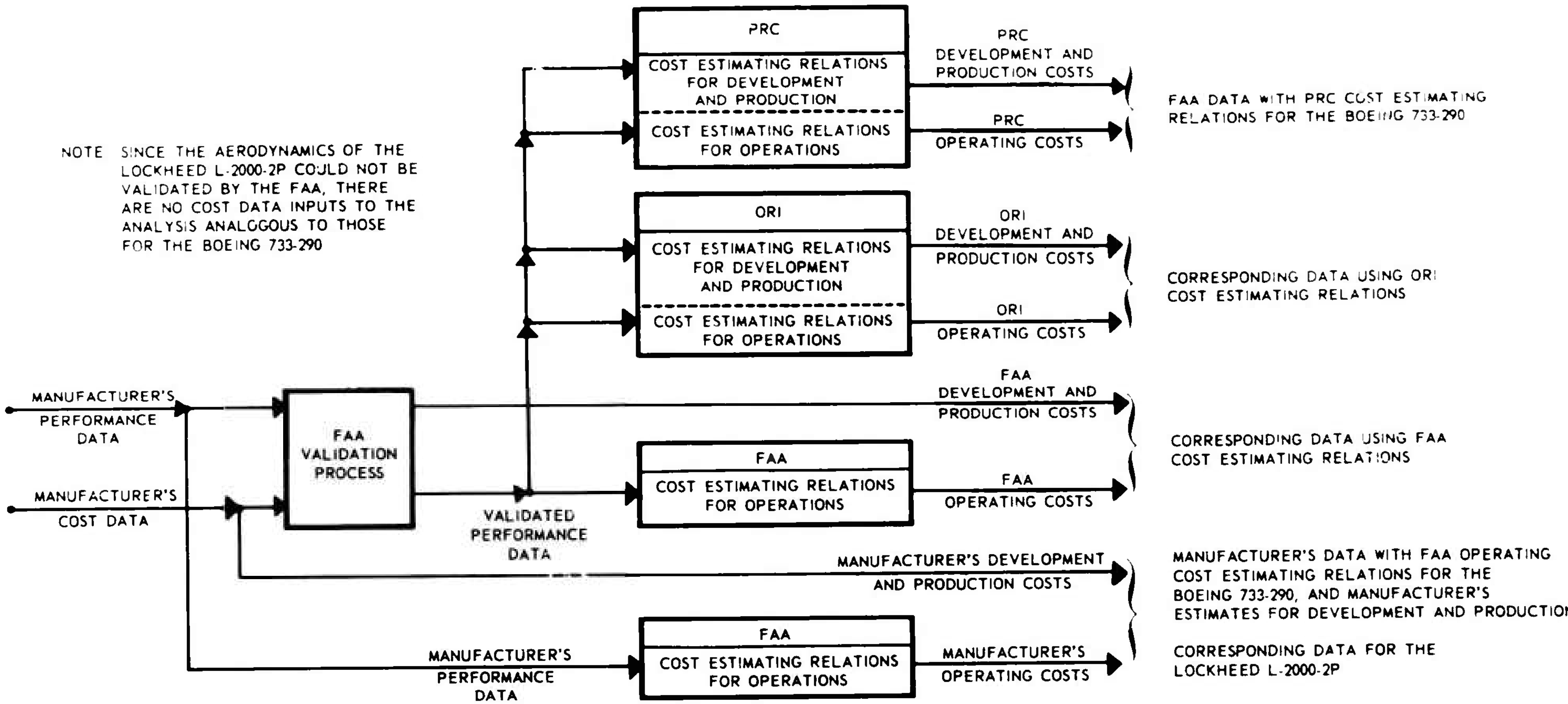

Figure A3.3. Variety of cost data input used in cost-benefit analysis of Boeing and Lockheed SST.

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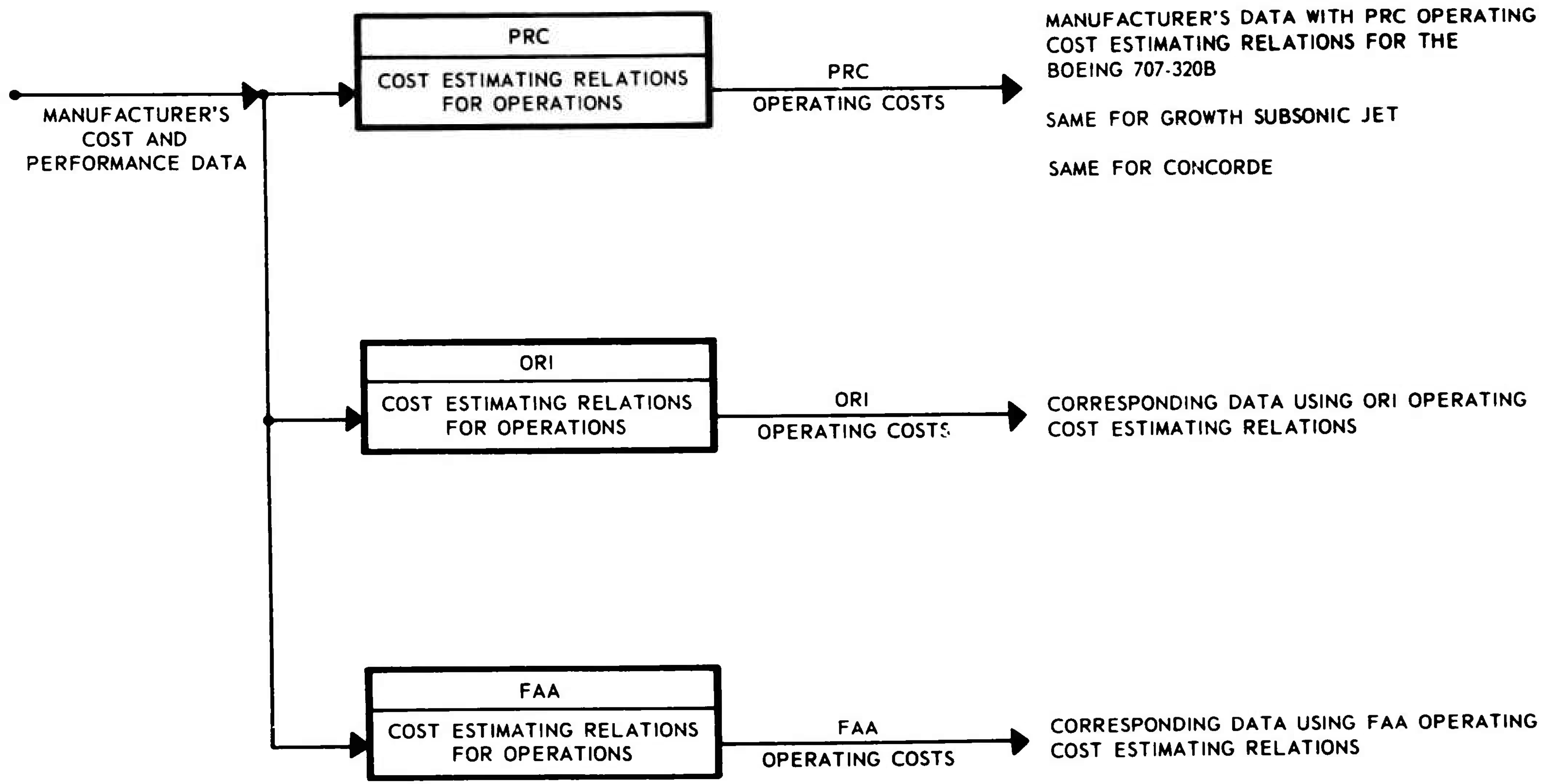

Figure A3.4. Variety of cost data input used in cost-benefit analysis of 707-320B, Growth subsonic and Concorde.

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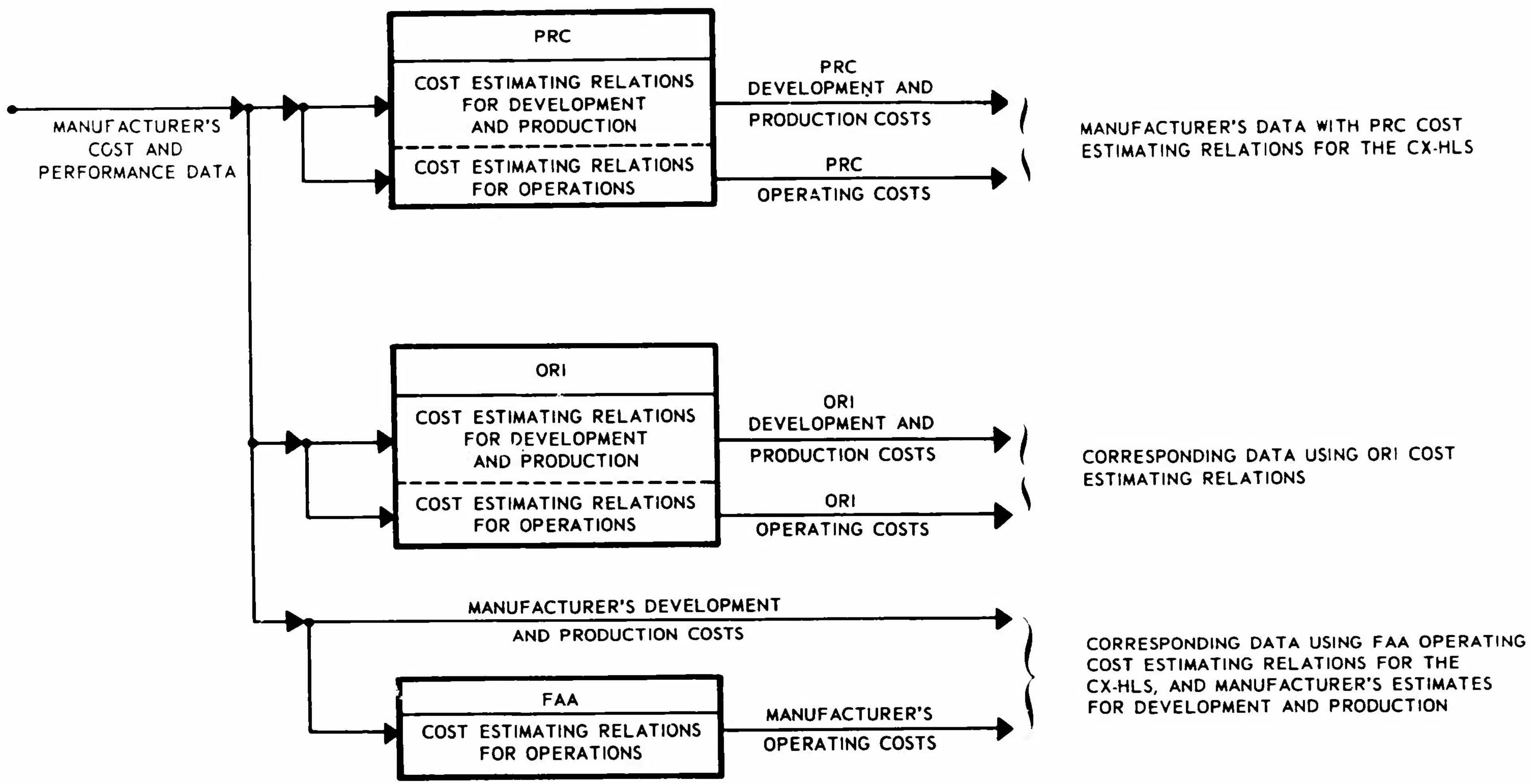

Figure A3.5. Variety of cost data input used in cost-benefit analysis of CX-HLS.

[redacted]

[redacted]

Table A3.1 Listing of Nominal Conditions for Analysis of Aircraft

Item	Boeing 733-290	Concorde	Boeing 707-320B	Growth Subsonic Jet	Commercial CX-HLS
Utilization	9 hrs/day	9 hrs/day	9 hrs/day	9 hrs/day	9 hrs/day
Load factor	Dom. 90% decreasing to 55% over 5 years; Int'l. 80% decreasing to 50% over 5 years	Same as for SST	Dom. 55% Int'l. 50%	Same as for Boeing 707-320B	Same as for Boeing 707-320B
Growth rate	Base rate	Base rate	Base rate	Base rate	Base rate
Route system	Case IV	Case IV	Case IV	Case IV	Case IV
Fare differential	+ 10%	+ 10%	0	0	- 10%
Aerodynamic data	FAA	Mfr.	Mfr.	Mfr.	Mfr.
Aircraft price	FAA (on 200 aircraft)	Mfr.	Mfr.	Mfr.	Mfr. (on 50 aircraft)
Cost estimating relations	FAA	FAA	FAA	FAA	FAA
Sonic boom	2.0/1.5	2.0/1.5			

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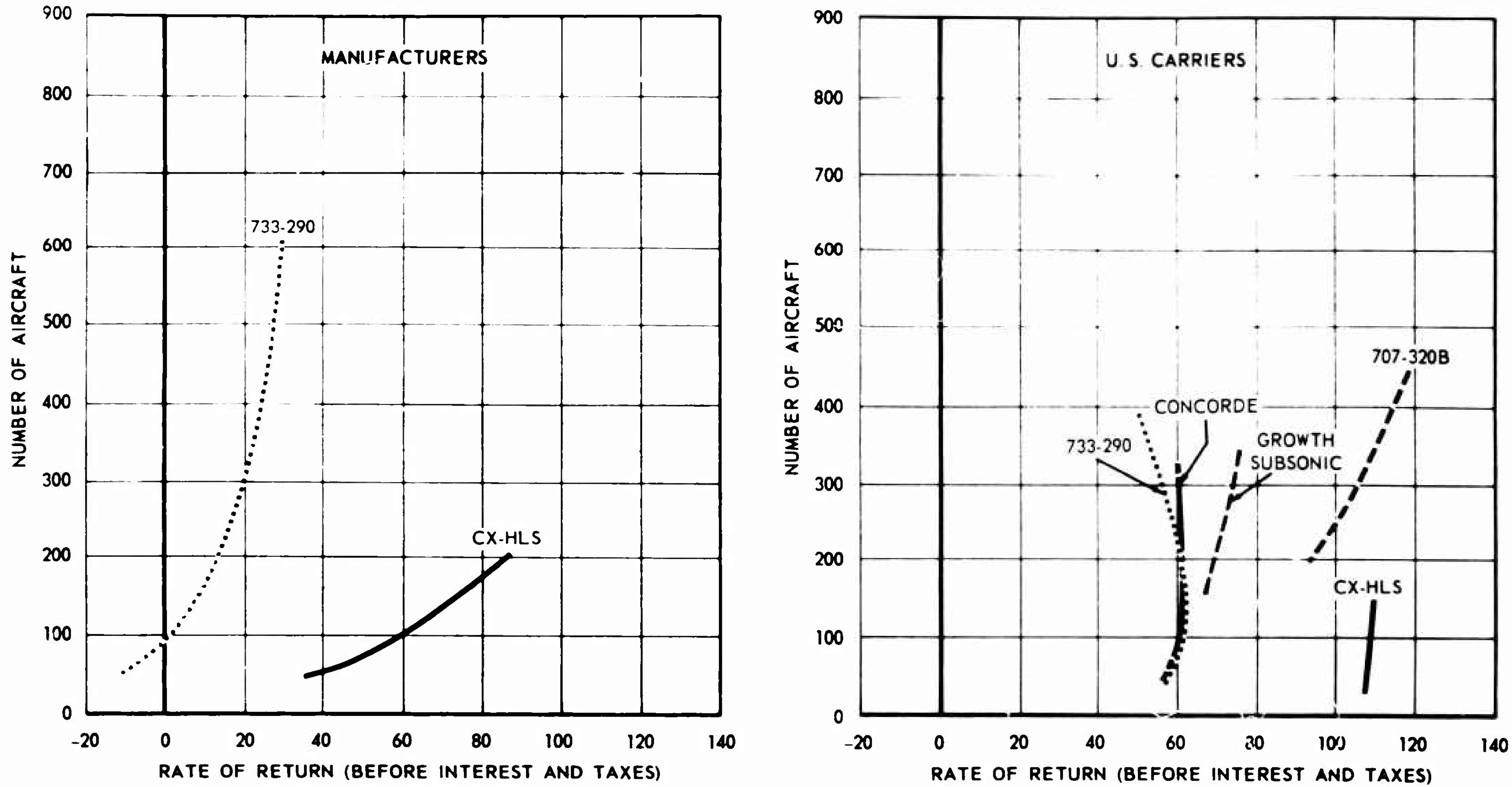

Figure A3.6. Degree of market success required for a given internal rate of return (before interest and taxes).

[redacted]

62 to 51 percent for the SST, and 106 to 108 percent for the commercial CX-HLS. The SST returns are based on full amortization of FAA-validated development costs and 10 percent differential above current subsonic fares; the CX-HLS returns, full amortization of the small cost of commercialization and 10 percent differential below current subsonic fares.

At the currently mentioned sales price, the Concorde returns to U.S. carriers are comparable to those of the SST; those for the current and growth subsonic are generally higher.

Figure A3.7 shows the sensitivity of the returns to the U.S. carriers for the costs estimated by each of the expert technical teams (manufacturer, FAA, PRC, and ORI). This represents a variation in the source of data input. It is assumed that any increases in development or production are reflected in increased aircraft sales price to the carriers. The returns to the carriers vary from 20 to 70 percent, about the nominal of 60 percent. The returns to the manufacturers varied slightly (by about 1 percent).

Figure A3.8 shows the corresponding sensitivity of the returns to both manufacturers and carriers for the commercial CX-HLS when its source of input data is varied, and the additional costs are reflected in the aircraft sales price. Carrier returns are approximately halved: manufacturers' returns are increased significantly.

Figure A3.9 shows the corresponding sensitivity of carrier returns for the Concorde when the source of input data is varied and the additional costs are reflected in the aircraft sales price. Carrier returns are decreased by at least 40 percentage points.

Figures A3.10 and A3.11 show the sensitivity of carrier returns for the SST to sonic boom. The first shows that carrier returns increase about 5 percentage points when flight restrictions are relaxed from 2.0/1.5 to 2.5/1.7 pounds per square foot overpressure. The second shows the effect of loss of markets when SST operations are restricted to overwater routes, leading to a decrease in carrier returns of about 17 percentage points at 132 aircraft in U.S. carriers fleet. This corresponds to a Free World fleet of 220 aircraft.

Figures A3.12 through A3.14 show the sensitivity of carrier returns to variations in load factor for the SST, commercial CX-HLS, and Concorde, respectively. A 5 percent variation in load factor produces about 5 percentage point changes in carrier returns for each aircraft.

Figures A3.15 through A3.17 show the sensitivity of carrier returns to variation in fare for the SST, commercial CX-HLS, and the Concorde, respectively. A 10 percent change in fare for the SST and Concorde produces about 10 to 15 percentage point changes in carrier returns; the same 10 percent change for commercial CX-HLS produces about a 20 point change.

Figures A3.18 through A3.20 show the sensitivity of carrier returns to variation in daily aircraft utilization (with 9 hours nominal). A 1-hour change in utilization for the Concorde and commercial CX-HLS produces about 10 percentage point changes in carrier returns; the same change for the SST produces about a 6 point change.

Figures A3.21 through A3.23 show the sensitivity of manufacturers and carrier returns to variations in aircraft sales price. A 5 percent change in sales price of the SST varies manufacturers' returns by 2 percentage points, and

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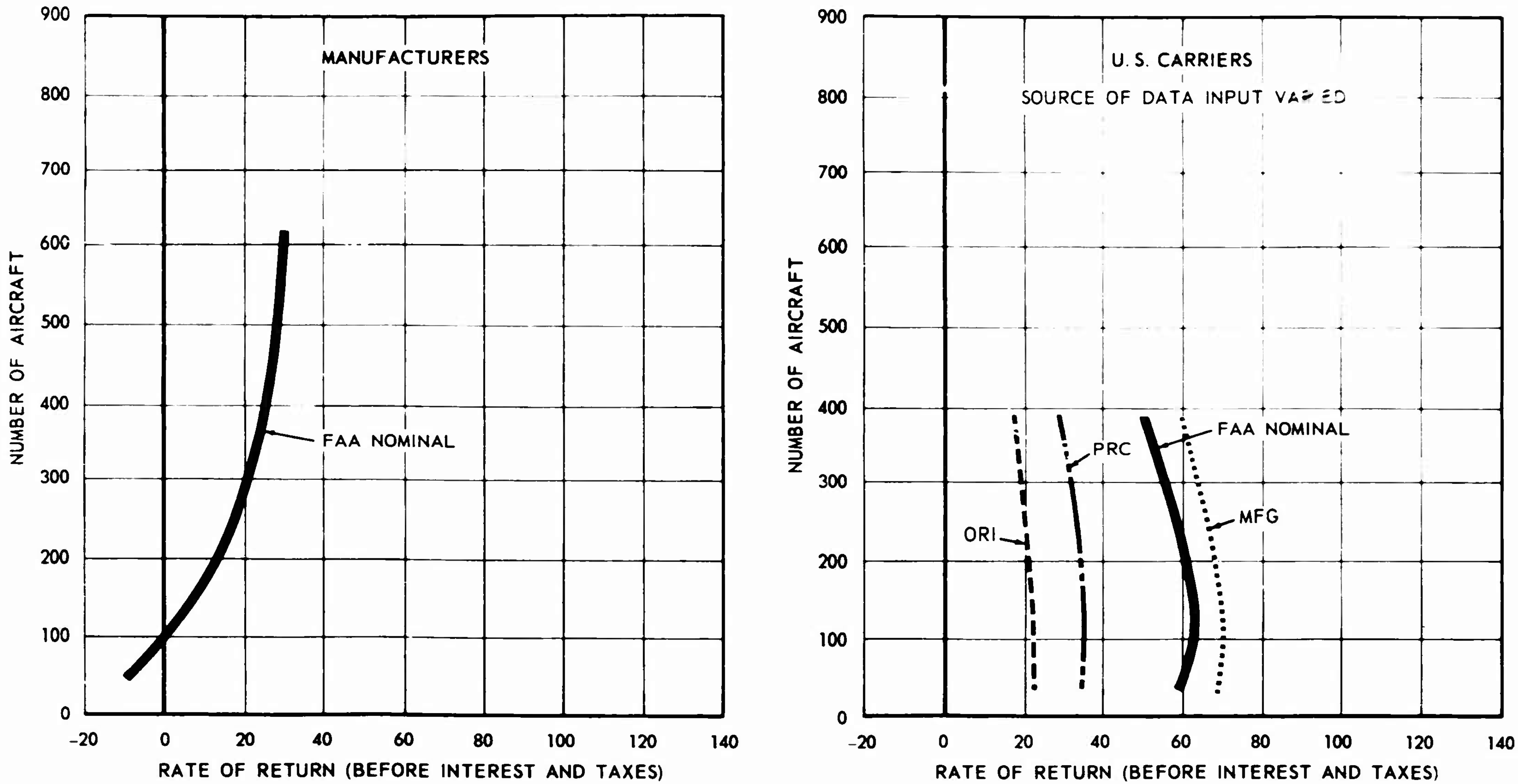

Figure A3.7. Variation in market success and in internal rate of return for Boeing 733-290.

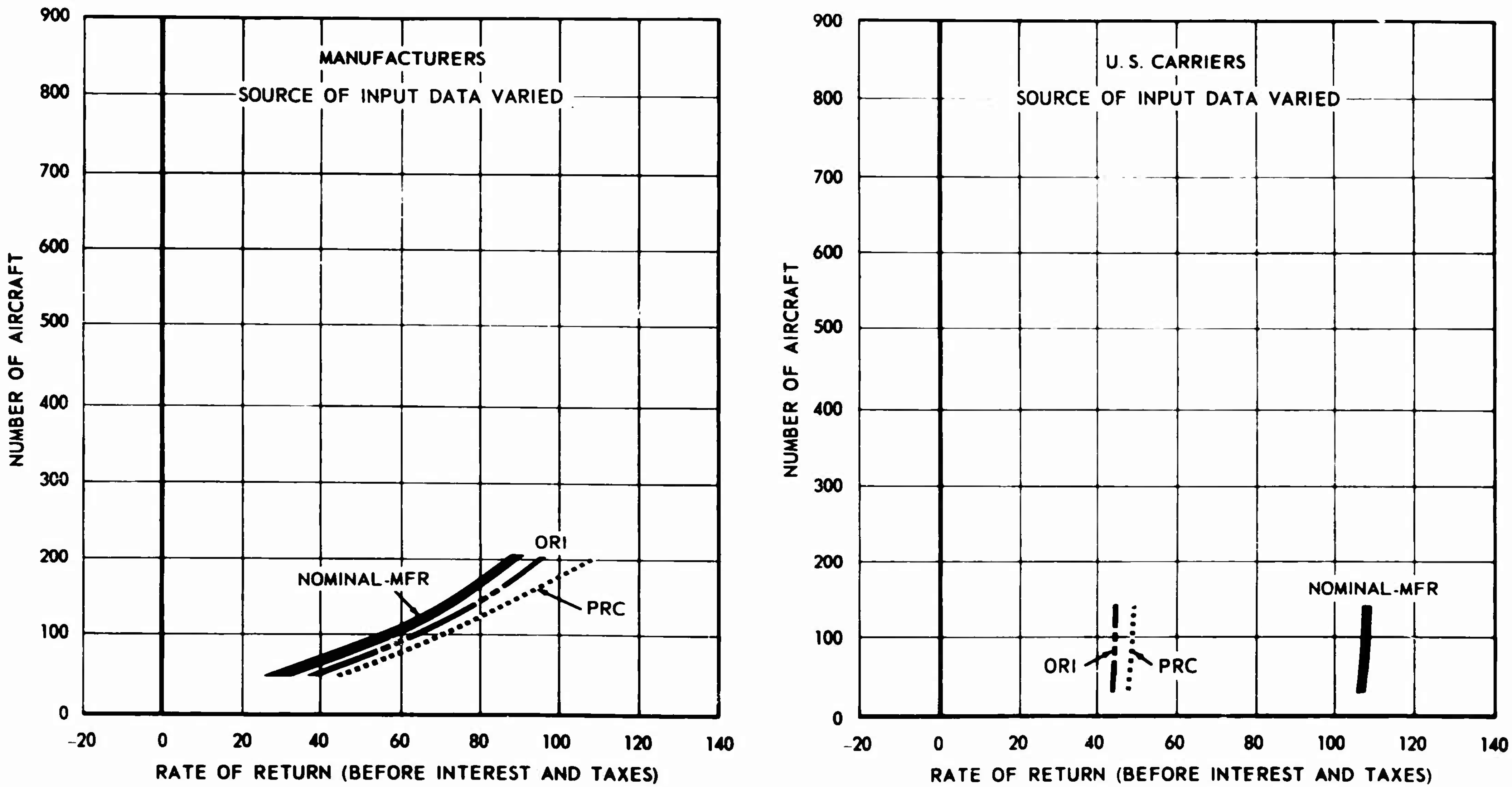

Figure A3.8. Variation in market success and in internal rate of return for Commercial CX-HLS.

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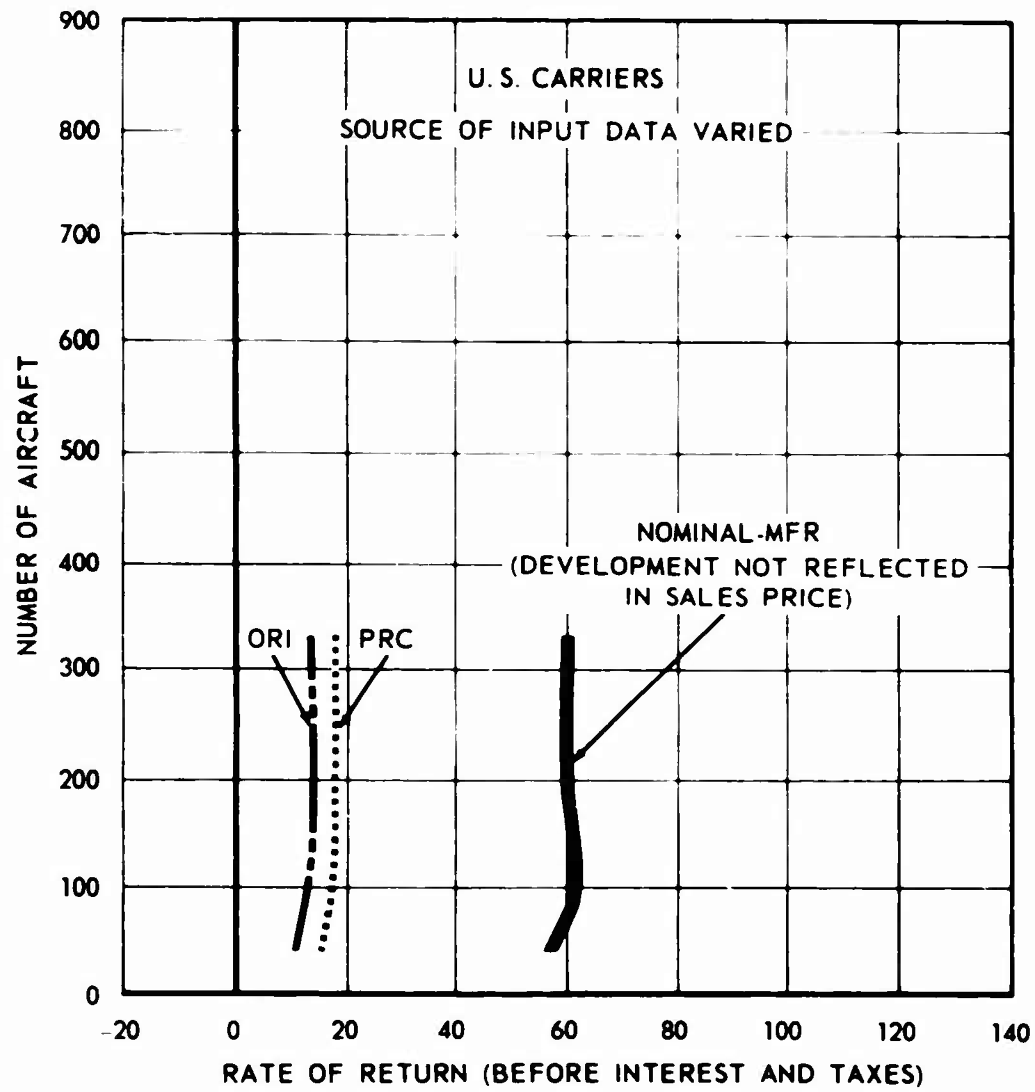

Figure A3.9. Variation in market success and in internal rate of return for Concorde.

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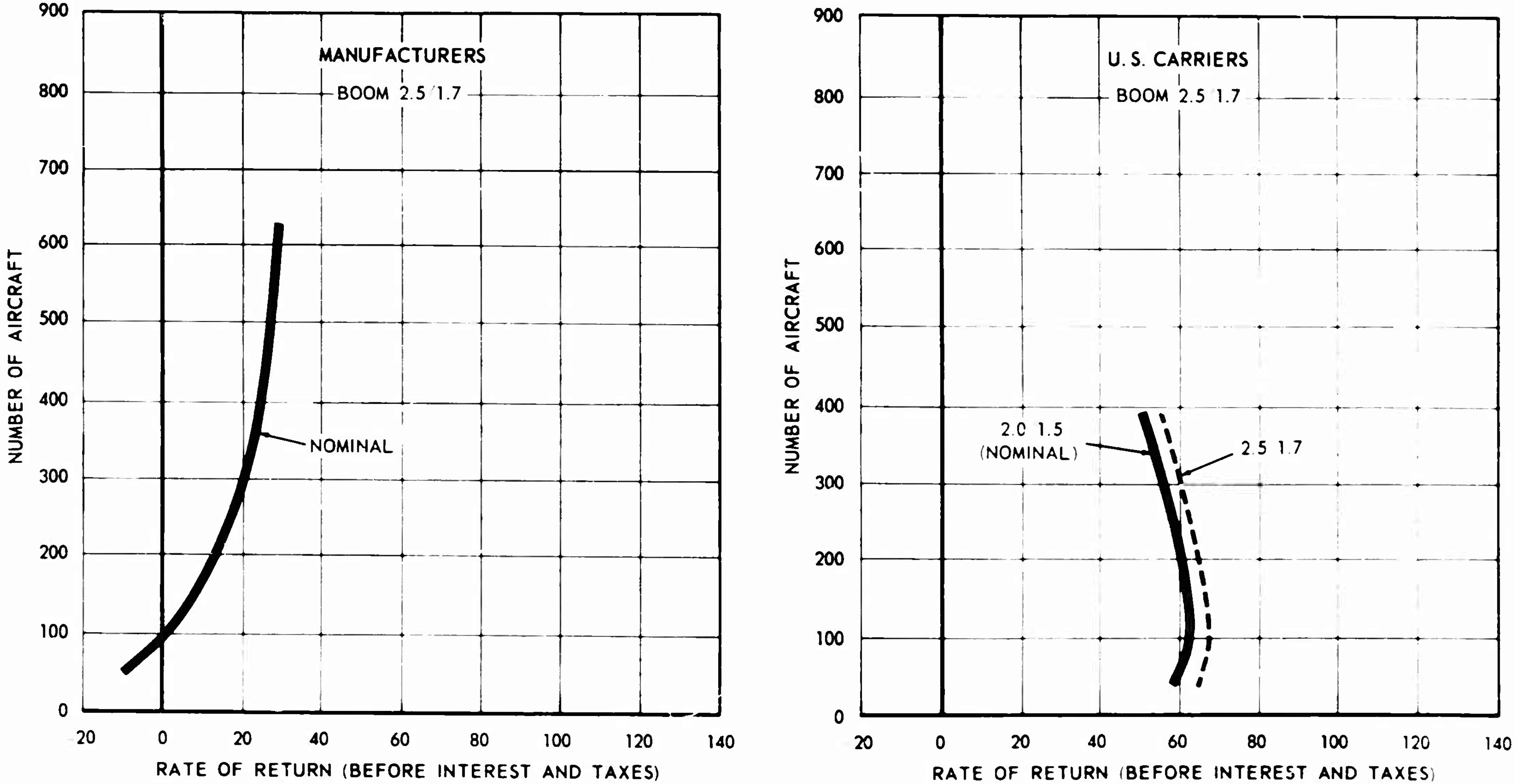

Figure A3.10. Variation in market success and in internal rate of return for Boeing 733-290.

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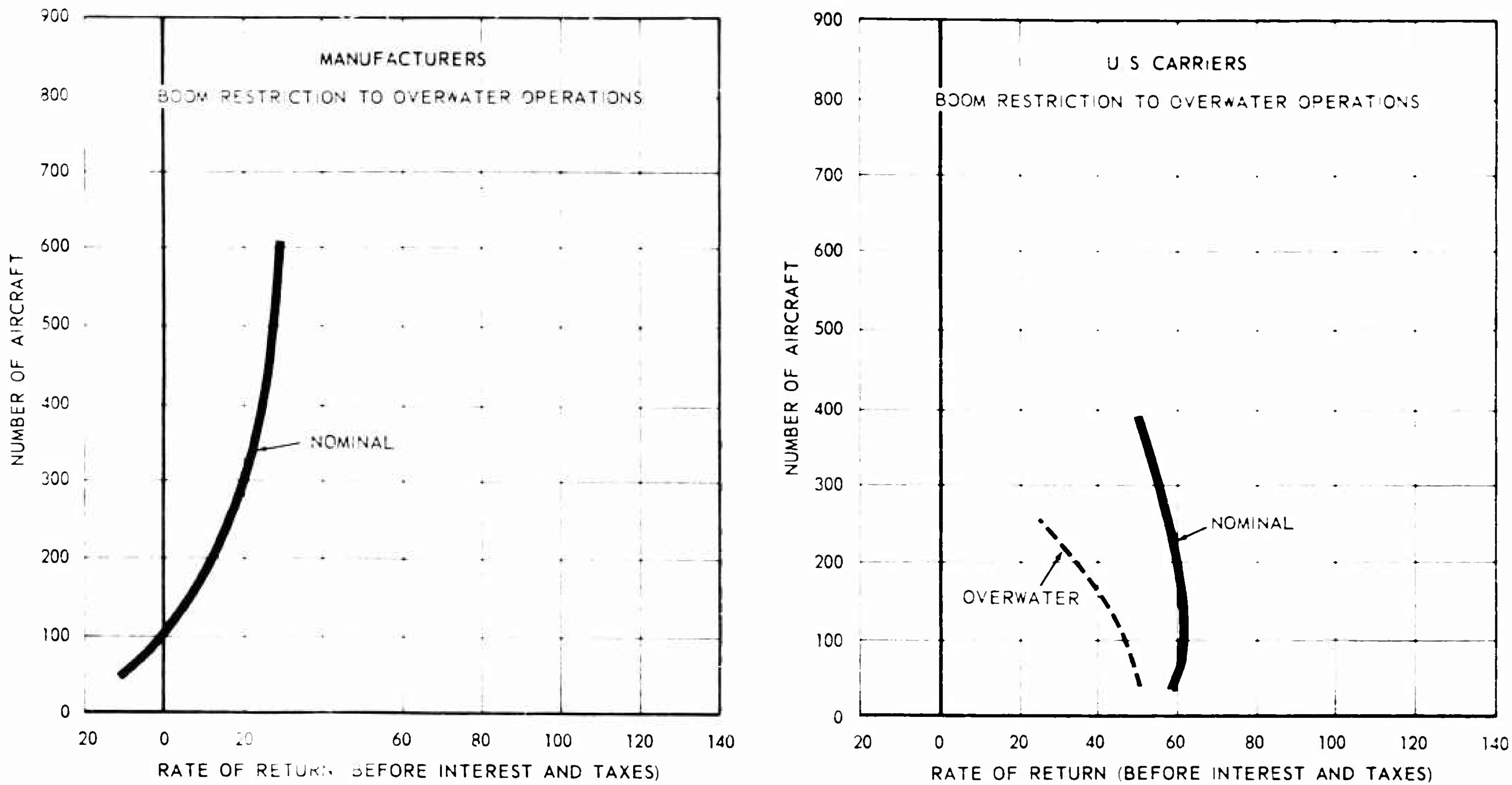

Figure A3.11. Variation in market success and in internal rate of return for Boeing 733-290.

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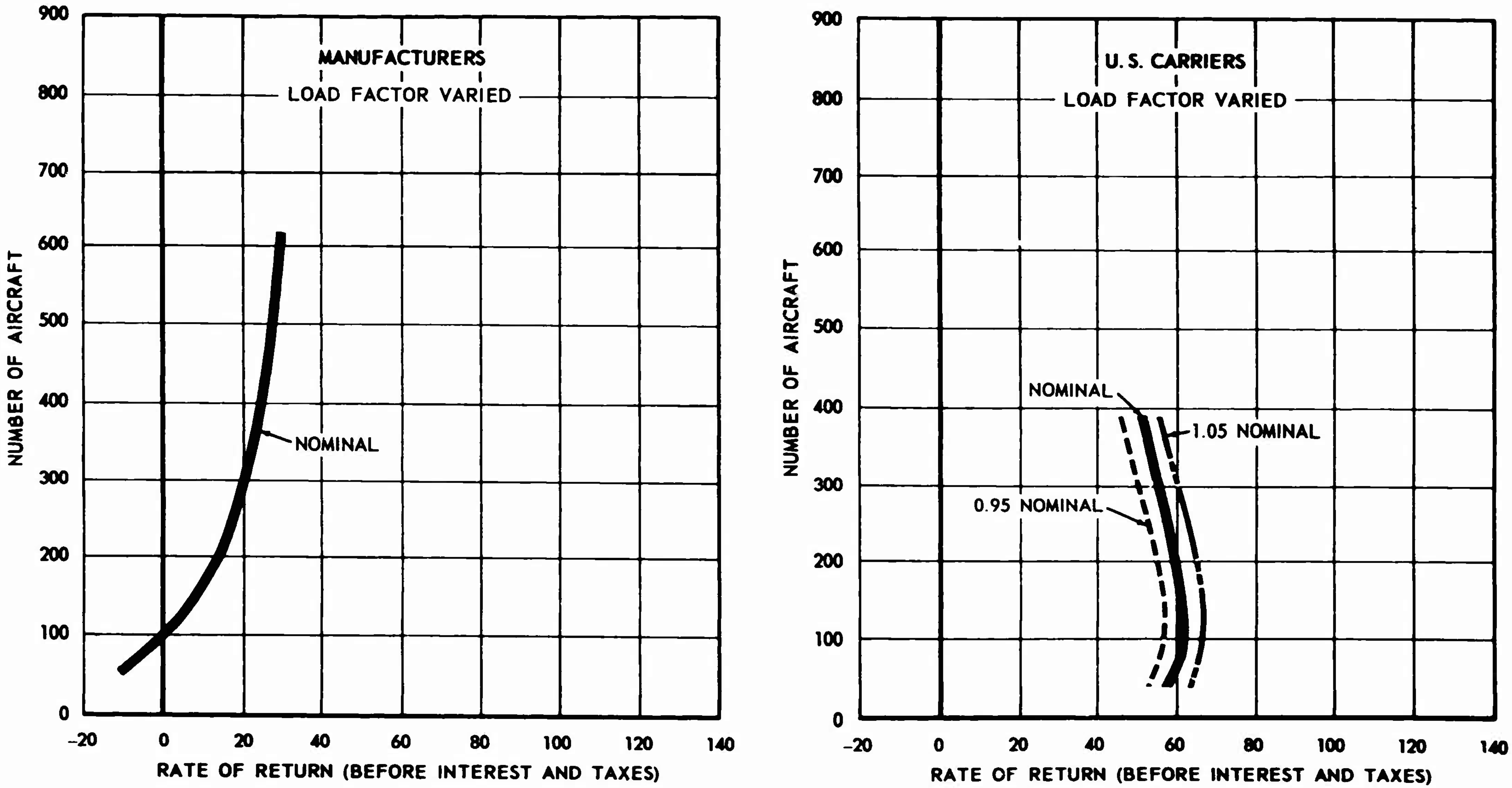

Figure A3.12. Variation in market success and in internal rate of return for Boeing 733-290.

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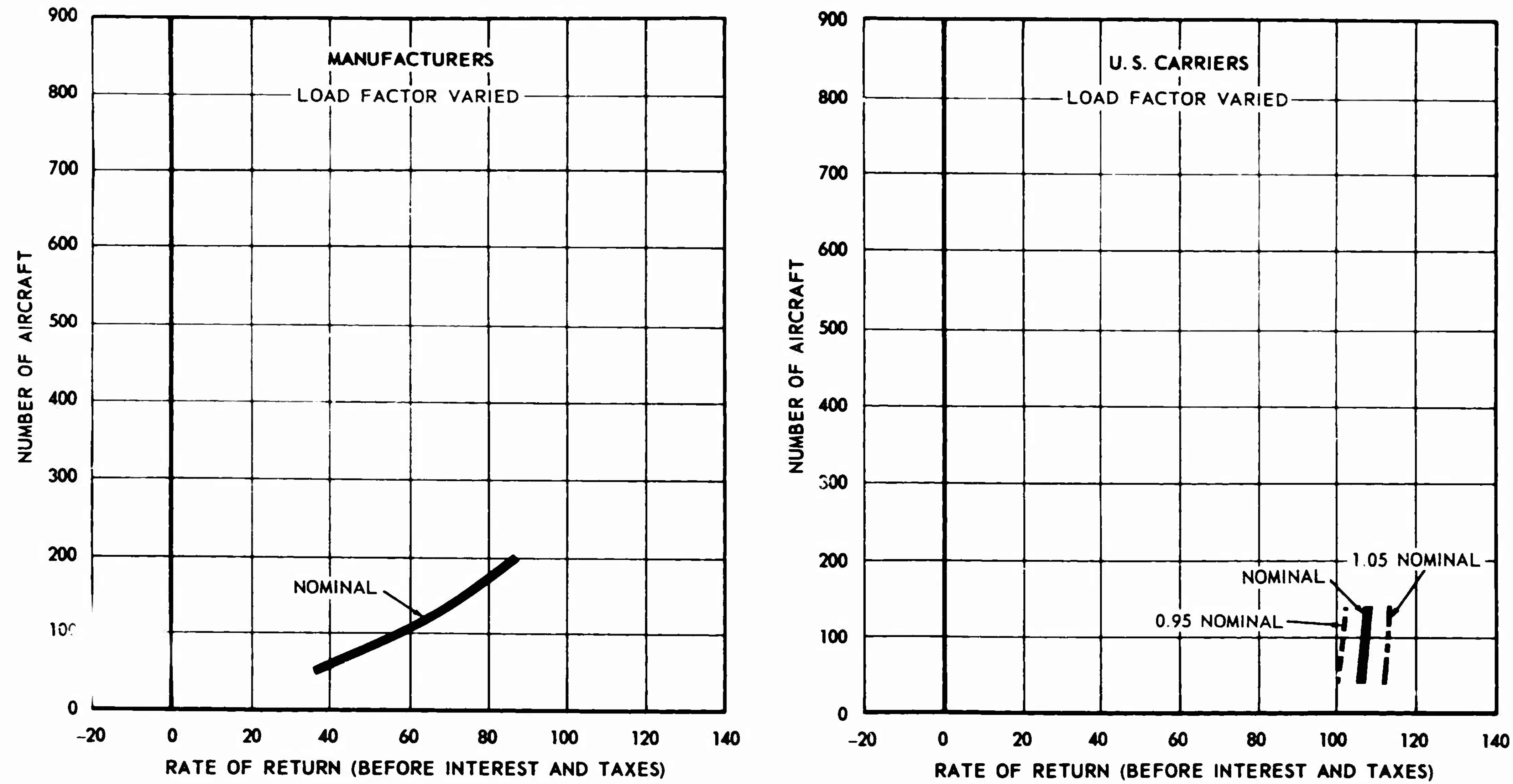

Figure A3.13. Variation in market success and in internal rate of return for Commercial CX-HLS.

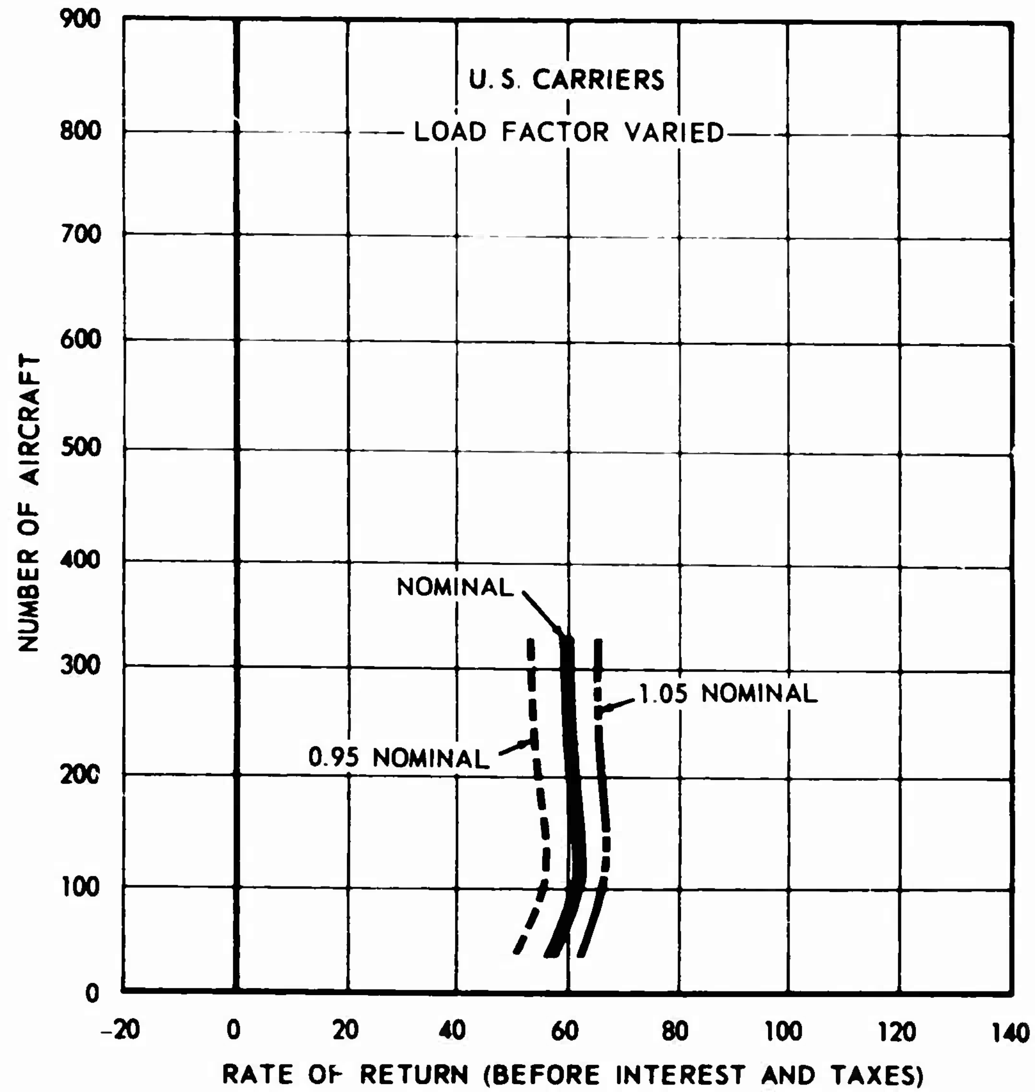

Figure A3.14. Variation in market success and in internal rate of return for Concorde.

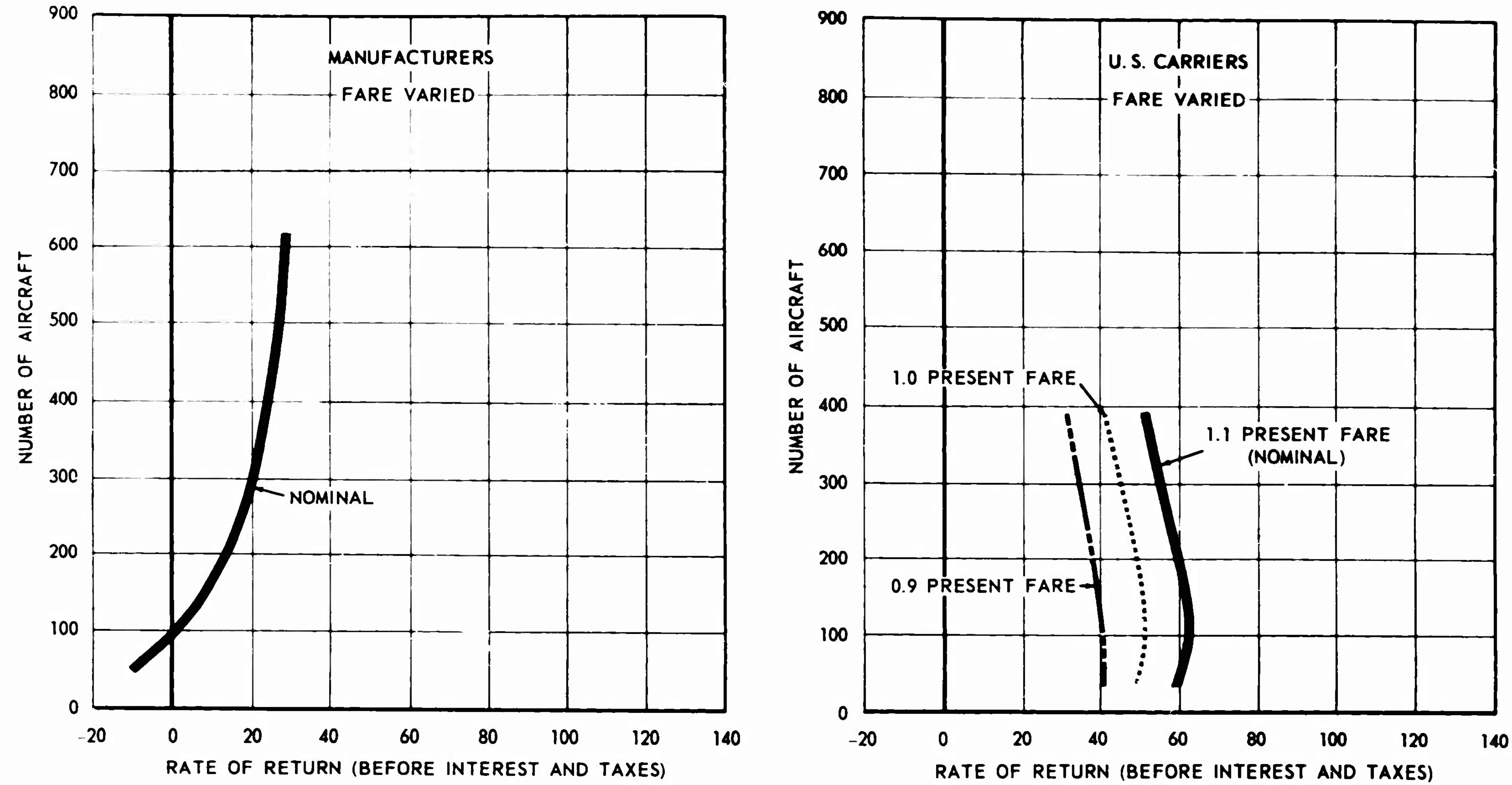

Figure A3.15. Variation in market success and in internal rate of return for Boeing 733-290.

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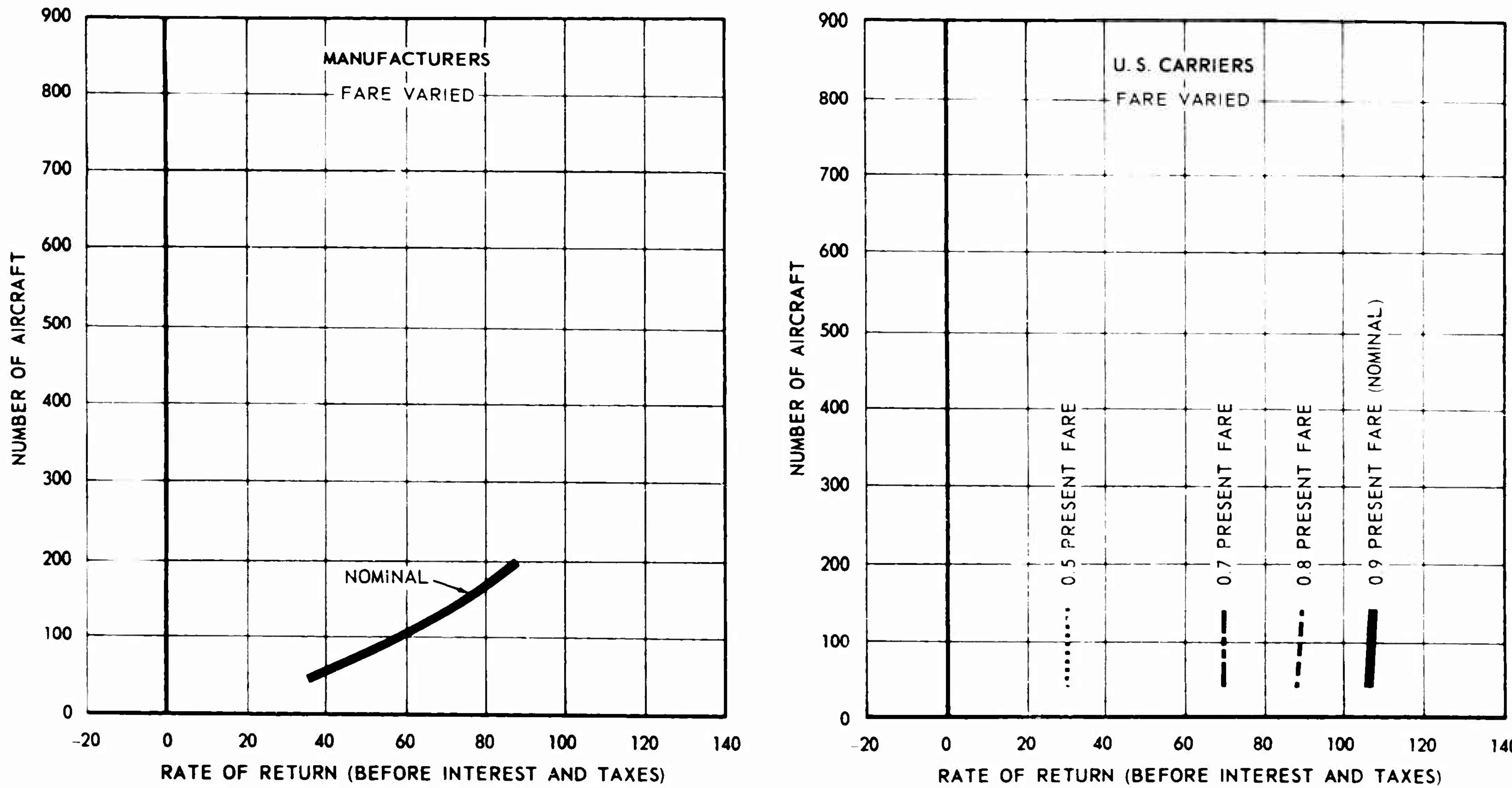

Figure A3.16. Variation in market success and in internal rate of return for Commercial CX-HLS.

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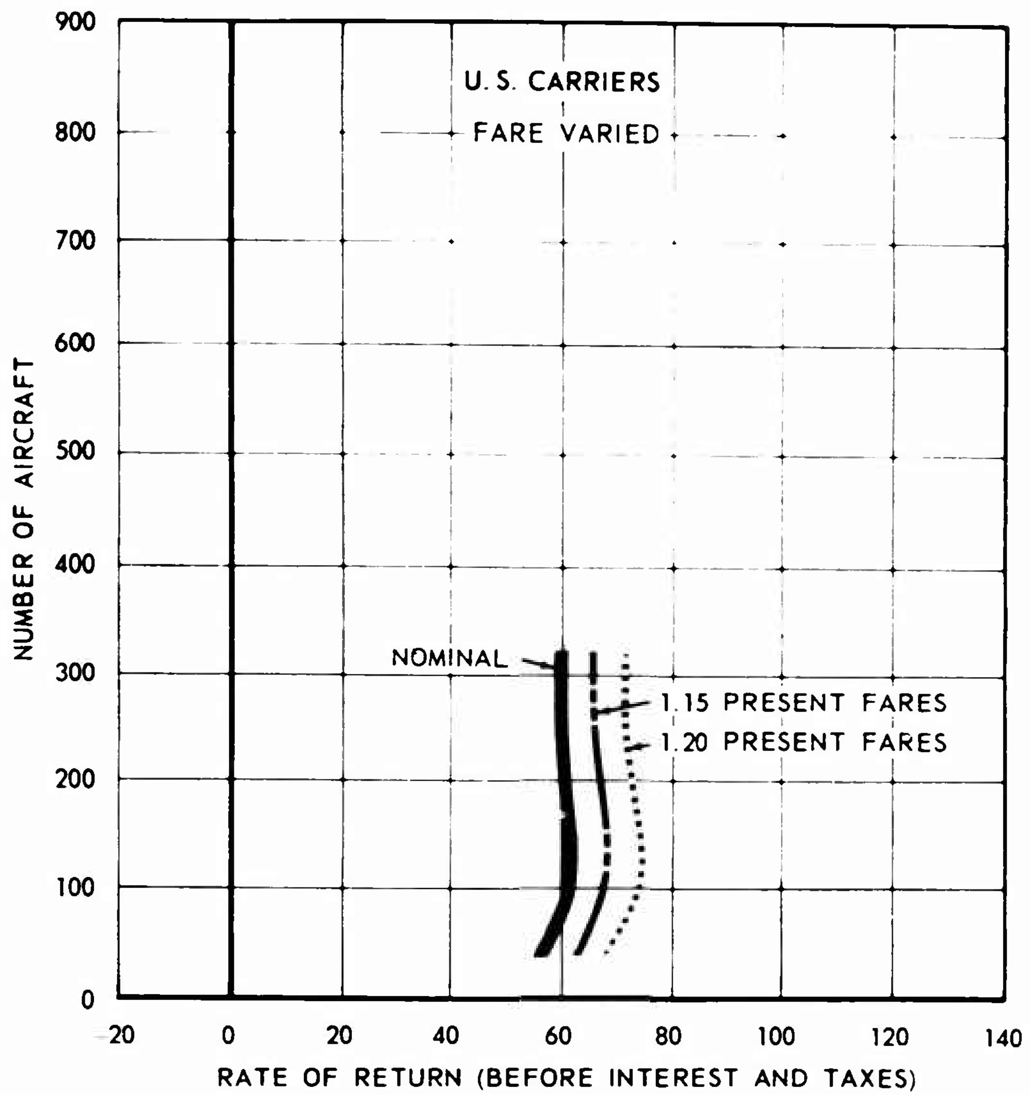

Figure A3.17. Variation in market success and in internal rate of return for Concorde.

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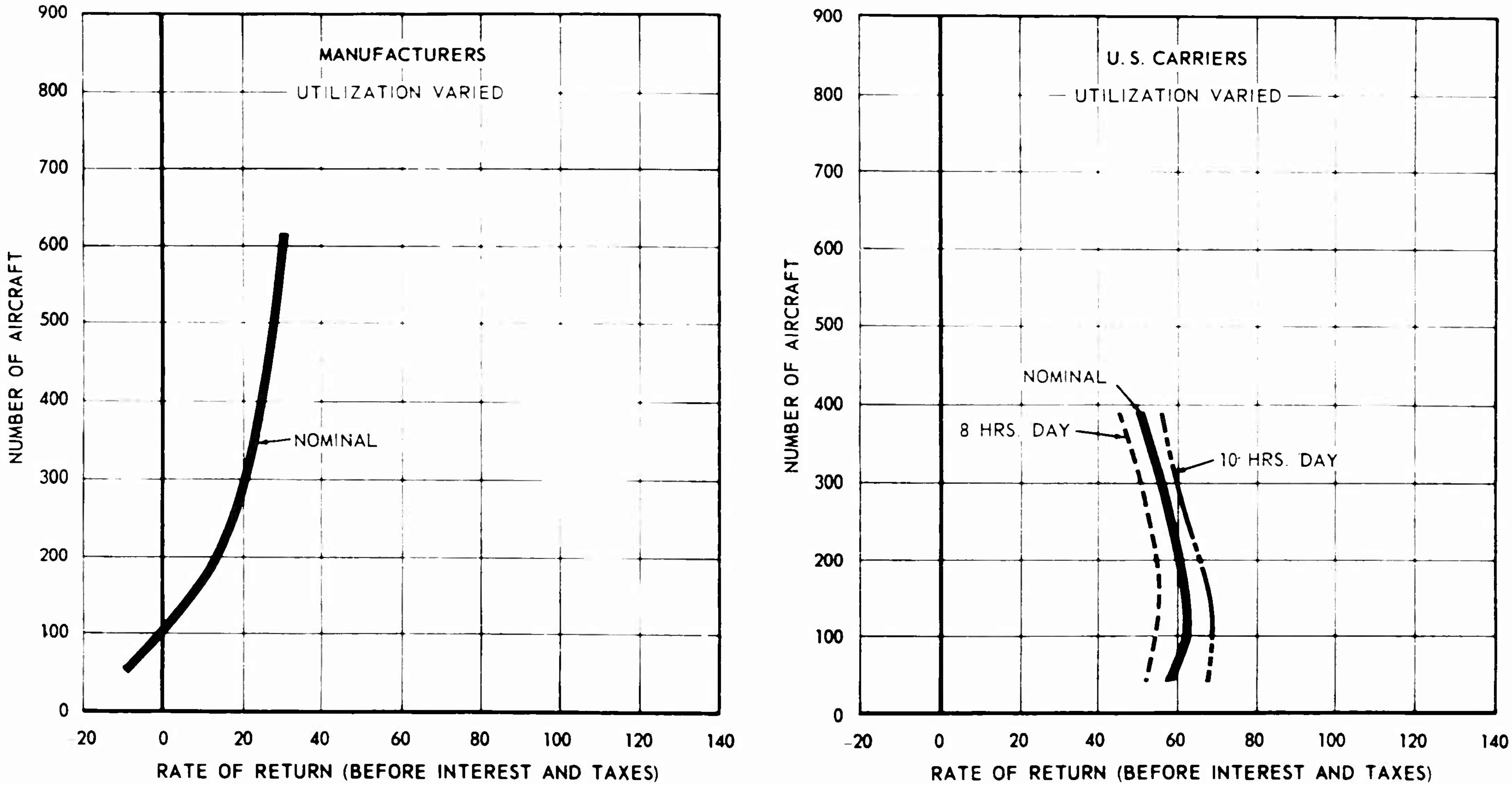

Figure A3.18. Variation in market success and in internal rate of return for Boeing 733-290.

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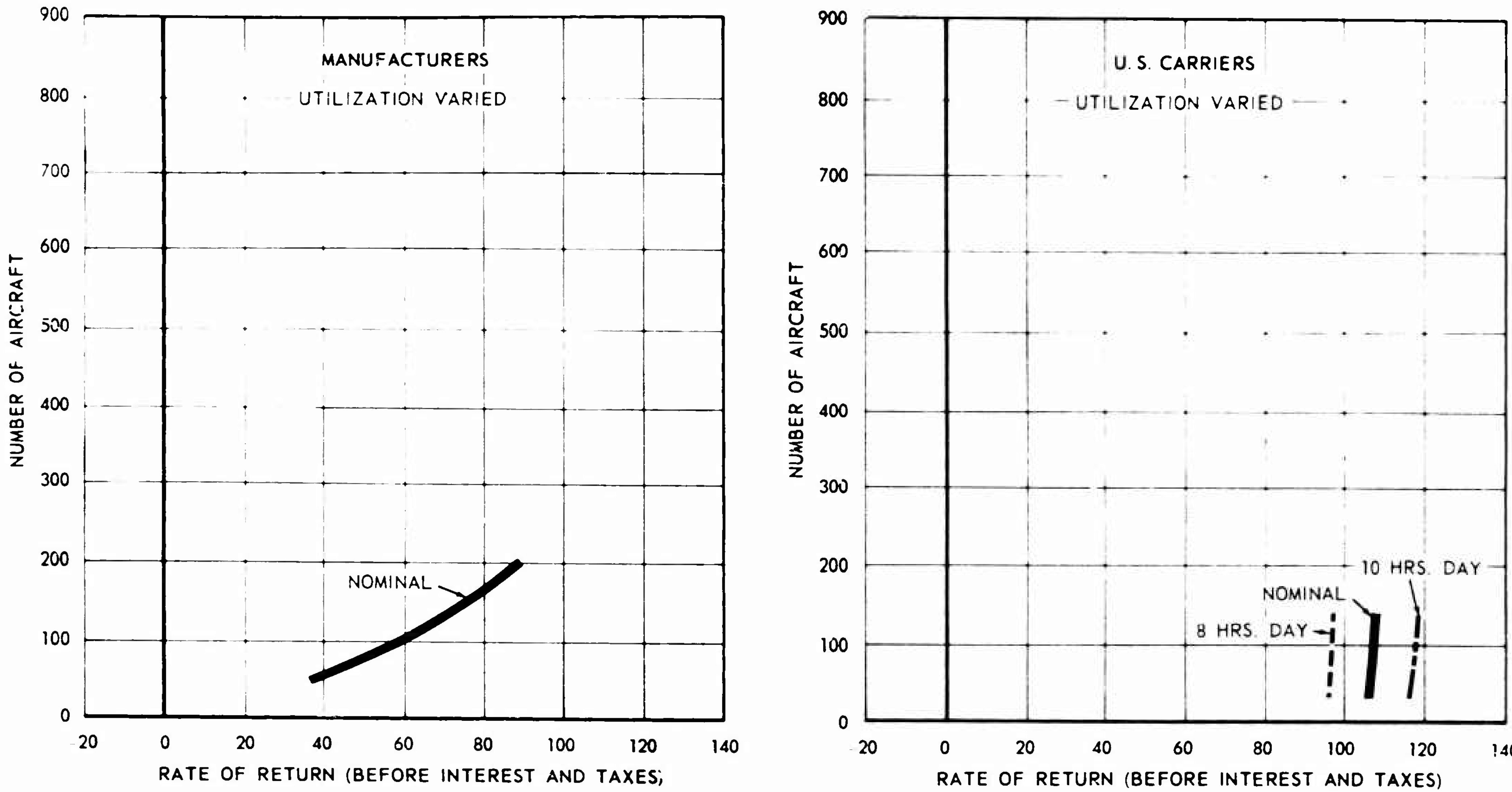

Figure A3.19. Variation in market success and in internal rate of return for Commercial CX-HLS.

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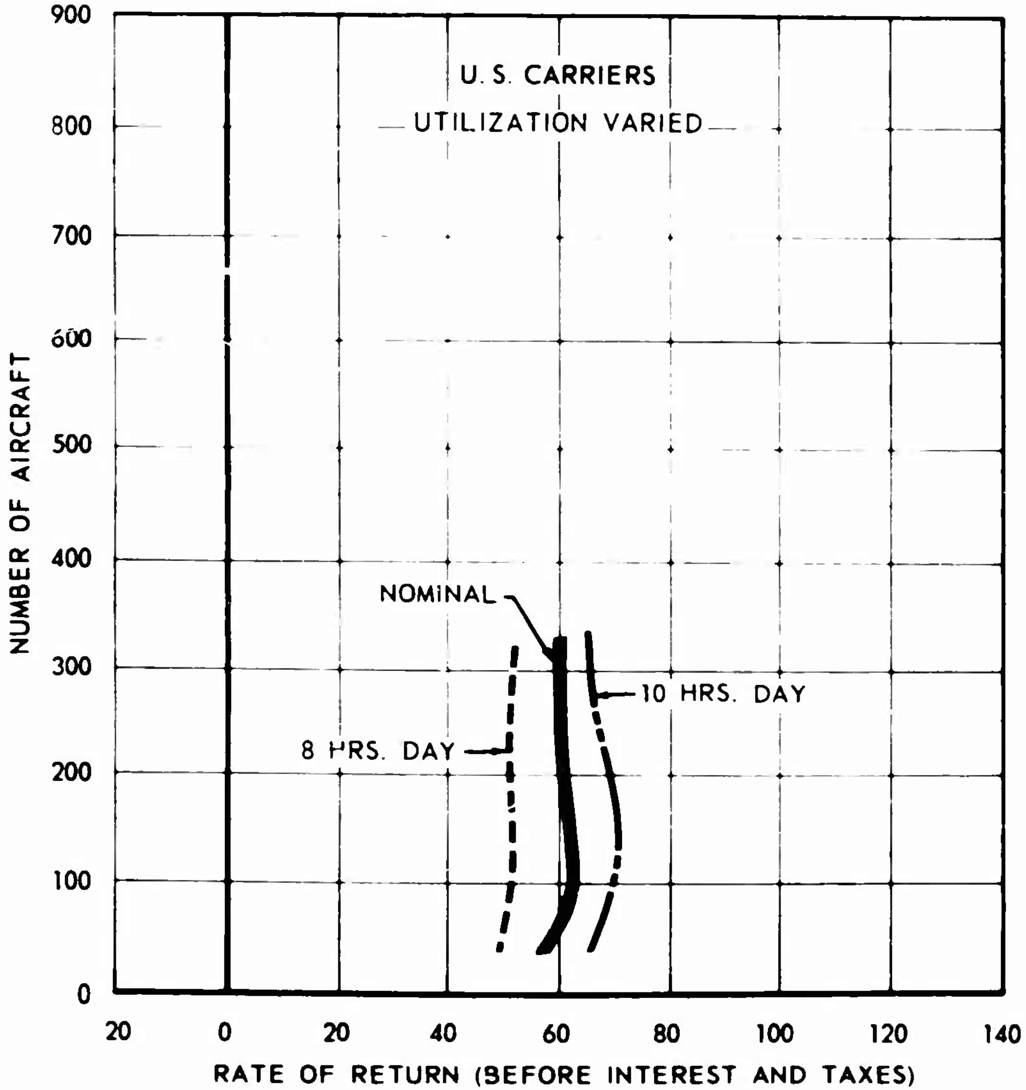

Figure A3.20. Variation in market success and in internal rate of return for Concorde.

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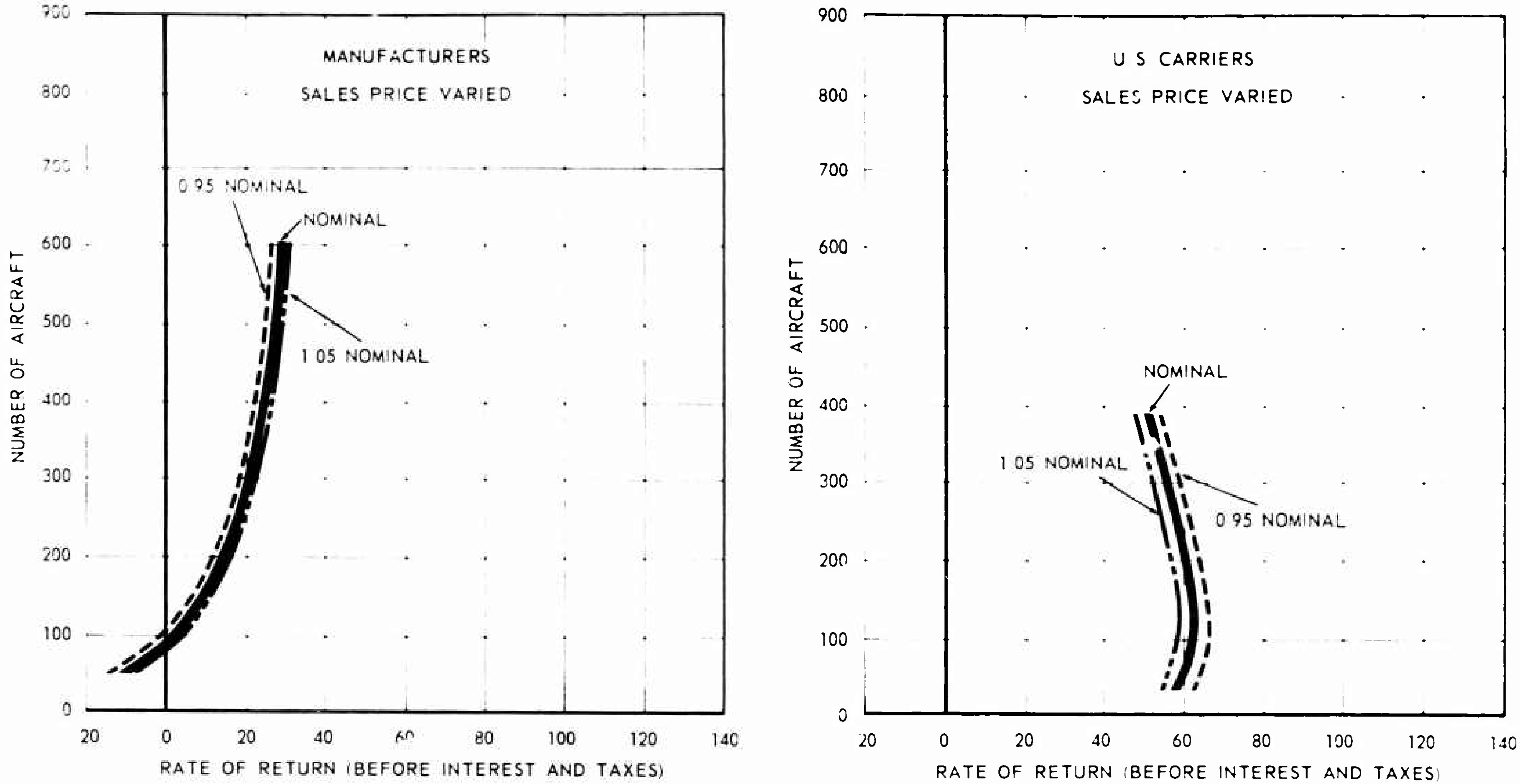

Figure A3.21. Variation in market success and in internal rate of return for Boeing 733-290.

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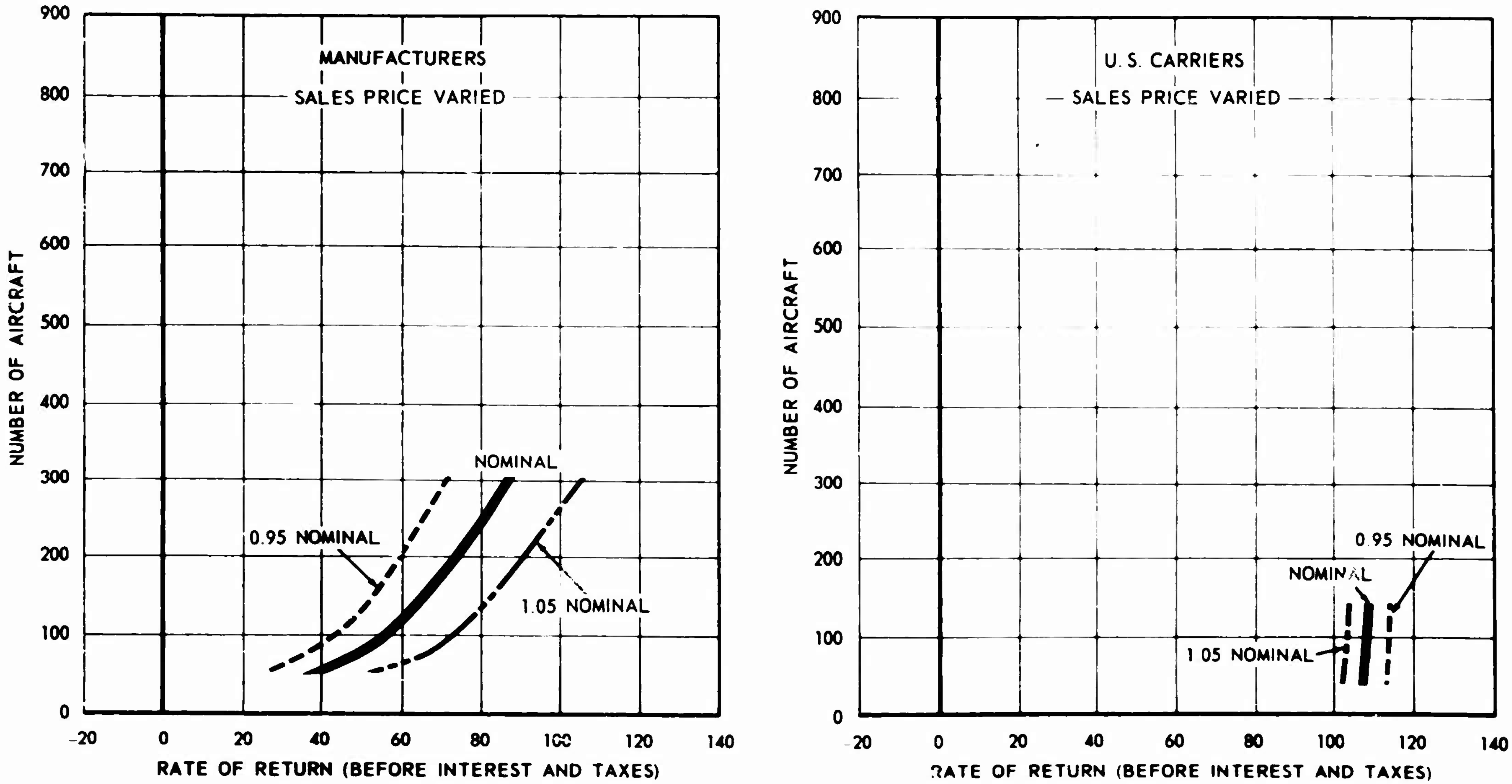


Figure A3.22. Variation in market success and in internal rate of return for commercial CX-HLS.

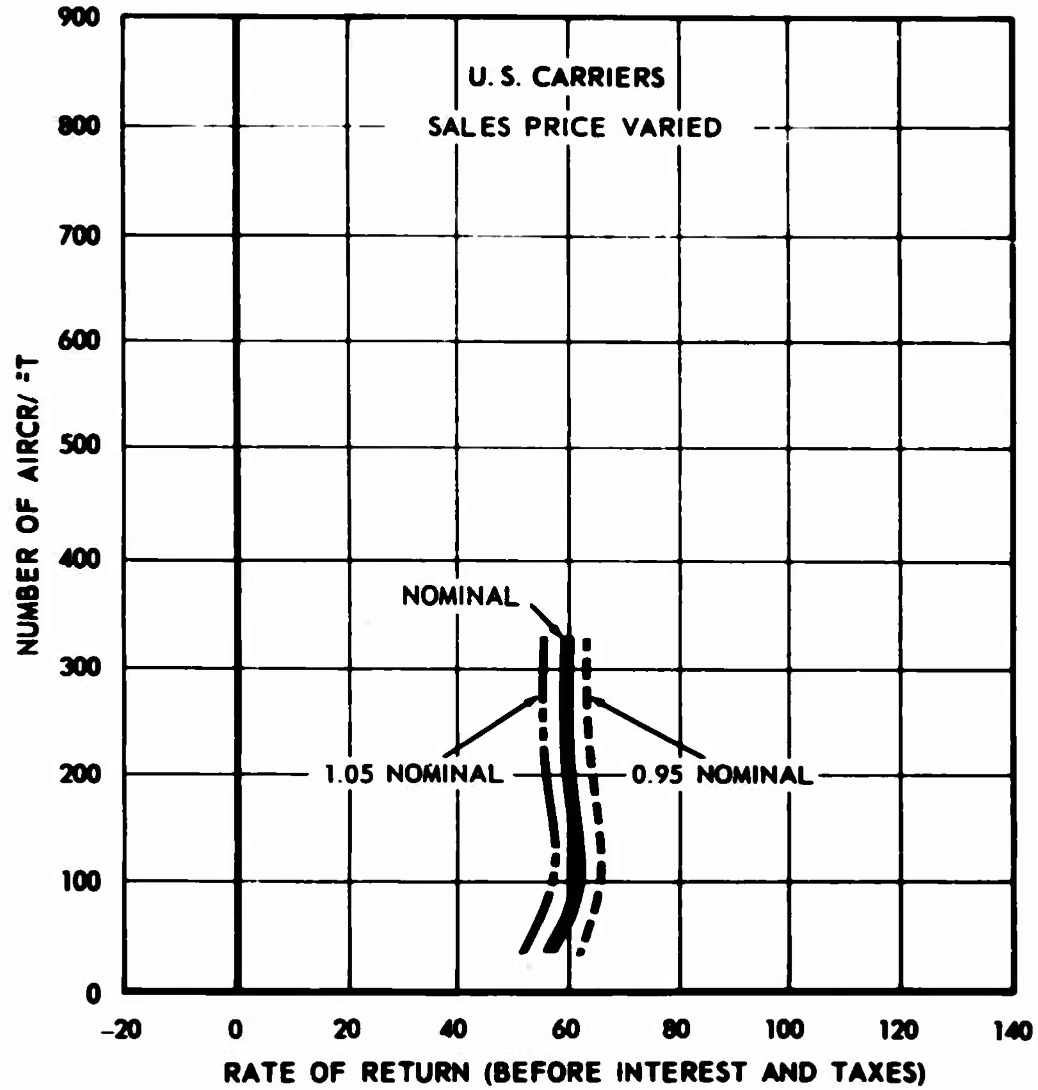


Figure A3.23. Variation in market success and in internal rate of return for Concorde.

U.S. carrier returns by 4 percentage points. A corresponding variation for the commercial CX-HLS produces a 14 percentage point change in returns to the manufacturers and a 5 percent change in returns to U.S. carriers. The corresponding variation for the Concorde produces a 4 percentage point change in returns to U.S. carriers.

The sensitivity analyses of other factors is continuing, and will be presented in subsequent reports.

A4. ECONOMIC SIGNIFICANCE OF SONIC BOOM

A4. ECONOMIC SIGNIFICANCE OF SONIC BOOM

The purpose of this section is to present the rationale for estimating claims costs resulting from sonic boom, and for examining the tradeoffs between these costs and aircraft operating costs for various flight procedures designed to reduce claims costs. While this study does not evaluate any of the psychological or emotional reactions to boom, it does examine the economic effects of political restriction of SST operations that might result from adverse reactions. Presently available data can yield only crudely approximate estimates. These estimates are nevertheless useful in providing perspective on the economic significance of boom. The results here presented were largely performed under contract by the Institute for Defense Analysis (IDA).

Data on claims resulting from supersonic operation of aircraft in the United States were reviewed. Since the great majority of claims are for damage to ground structures, a preliminary study was made of structural responses to sonic boom as an aid in interpreting claims data and in extrapolating claims costs from smaller aircraft to the SST. A relationship between claims cost and population exposure to boom was developed for the United States. This relationship was then used to project tradeoffs between claims costs and the cost of modifying U.S. domestic SST operations so as to reduce claims.

Claims costs resulting from SST operations over foreign routes will probably be quite different from those of comparable U.S. domestic routes because of differing types of ground structures, and differing construction materials, techniques and standards. Moreover, the procedures for adjudicating claims in foreign countries may differ significantly from that for the United States. Accordingly, foreign routes were categorized only qualitatively according to the number of people boomed, the ease of avoiding population, and the type of ground structures subjected to boom overpressures.

A4.1 VALIDITY OF ANALYSIS

The two basic sources of claims data studied were claims resulting from normal U.S. Air Force supersonic operations in the United States and from the Oklahoma City test claims. As between these sources, the Oklahoma City data are believed to be more representative of future SST operations since the experiment was specifically designed to simulate the SST boom environment. At this writing (February 1965), claims resulting from the Oklahoma City tests were still being received by the Judge Advocate's Office at Tinker Field at a rate of about 10 per week. Furthermore, litigation involving past claims is a continuing possibility. Accordingly, the present pattern of claims costs at Oklahoma City could be changed by the time the books are closed on that experiment. Our judgment, however, is that the Oklahoma City pattern will not be drastically altered by claims not yet submitted or evaluated, or by future litigation of claims.

The filing of claims involves emotional as well as purely physical factors. Hence, the claims resulting from commercial SST operations (over a long period of years, involving night as well as daytime operations, and much higher frequency of booms) could be very different from the Oklahoma City pattern. Notwithstanding this possibility,

the Oklahoma City data provide the best means presently available for projecting the general level and pattern of SST claims.

A4.2 THE COSTS FOR SST OPERATIONS

The economic significance of sonic boom may be summarized in the following equation:

Total Costs for SST Operations	=	Cost for operating with "normal" flight procedures
	+	Cost of boom damage
	+	Incremental cost for operating with flight procedures designed to minimize boom effects
	+	Loss of airline revenues due to political restriction of routes or to reduced demand for SST travel because of smaller trip time differential over competing subsonic aircraft

Let us examine the several cost categories entering into the total costs for SST operations. The first deals with the cost elements incurred if boom effects on the ground were negligible, and the SST were operated using "normal" flight procedures. With such "normal" procedures, the SST would fly a standard flight profile over the standard distance between a pair of cities, allowing for variations due to abnormal weather or operational conditions. The direct and indirect elements of this operating cost would be determined by means of cost estimating relations such as those developed by Planning Research Corporation and Operations Research, Incorporated (our cost-performance contractors). The latter three categories of cost, however, derive from the fact that, with the present state of knowledge, boom effects on the ground cannot be made negligible.

Cost of Boom Damage

The cost of boom damage may be divided into two elements:

a. the cost of handling and investigating claims of damage to physical structures,

b. the cost of compensating claims.

To the extent that the Oklahoma City test results may be assumed to be representative of future SST operations, our studies show the following:

a. SST operations should not damage the basic structure of reasonably well-constructed buildings. Occasional damage to residences will, therefore, be minor and involve only bric-a-brac and secondary structural elements such as plaster, interior surfaces, and glass. Damage to commercial, industrial, and other non-residential buildings should be limited to only occasional glass breakage.

b. Alleged damage to ground structures comprise by far the largest category of claims. Total claims costs appear to be directly proportional to the number and value of the buildings overflown, which for the U.S. are approximated in this study by the population overflown. At the flight frequencies used (eight per day), the Oklahoma City claims data appear representative of the U.S. and Canada during the SST operations. However, the claims

data may differ substantially when any given area experiences much higher boom frequencies (10 to 20 times that of the Oklahoma City tests). Moreover, they are almost certainly not representative of the situation that may be found in other areas of the world. Based on the Oklahoma City data, the major item of cost was administrative handling of the claims; actual payments for alleged damages were small.

c. Alleged damage does not appear to depend on the level of overpressure within the range of overpressures experienced at Oklahoma City. This range covers the SST design specification of 1.5 to 2.0 pounds overpressure. The claims of damage arising from transonic acceleration or deceleration and from aircraft maneuver (except under emergency conditions) at cruising speeds may be kept quite small by choice of an isolated geographic area.

To compute claims cost, IDA has developed three claims cost estimating relations:

a. A person-boom relation which assumes that claims costs are directly proportional to the number of times a given population is boomed per day. Of the three estimating relations, this one will tend to produce relatively high estimates for future annual claims costs.

b. A person-day relation which assumes that claims costs are constant per day irrespective of the number of booms, so long as the given population is boomed at least once per day. This relation will produce relatively low estimates for future annual claims costs.

c. A best-judgment relation based on a statistical analysis which produces estimates lying between the person-boom and person-day relations, exceeding the latter by about 30 percent at a daily boom frequency of 18.

When these various estimating relations are combined with appropriate dollar values per claim, IDA can then estimate a range of probable claims costs per annum, together with a best-judgment estimate within that range.

Incremental Cost of Abnormal Procedures

In order to avoid some of the effects of boom, an airline must utilize abnormal flight procedures. Such procedures would include circuitous routing to avoid densely populated centers, and additional operations at subsonic speeds. Since such subsonic operations yield benefit at a very high incremental cost, they can be used only to a minor extent.

Up to a point, IDA found that claims cost could be reduced by abnormal flight procedures at relatively small increase in operating cost. However, further restriction of operations by circuitous routing tended to increase costs faster than the savings realized.

Our own analyses of the utility of abnormal procedures over U.S. domestic routes, and our discussions with airline personnel lead us to question whether circuitous routing offers as much benefit in the minimizing of boom effects as suggested by IDA. The variability of weather over the U.S. airline system suggests that it will be difficult to maintain the flights of the SST through carefully restricted channels which take due account of air traffic control and other operational requirements. Moreover, the likelihood of political restrictions of SST operations may increase if the people

[redacted]

continually overflown in these SST-designated channels conclude that they are bearing an undue portion of the social costs associated with the SST.

Loss of Airline Revenues

The use of abnormal flight procedures (whether to minimize claims costs or to conform to political restrictions) will generally have the effect of increasing SST trip-time and/or decreasing payload. For those markets in which the SST may compete against the advanced subsonic aircraft, the traveler will compare the two services offered with respect to their relative fares, trip-times, comfort, safety, convenience, prestige, etc. Depending on the extent of increase in SST trip-time and on the travelers' total preferences, the airlines providing SST service may suffer a loss in revenues.

Such losses in revenues may be expected to be significant only in the medium range markets (i.e., with route distances of 900 to 1500 statute miles) which are separated by densely populated regions. In these markets, the trip-time differential of the SST over the subsonic is small even under "normal" flight procedures, and hence the traveler would have less incentive to pay a fare differential for a marginally better SST service. The effects of such increased trip times on airline revenues over the route system will be examined in subsequent analyses.

Boom restrictions in climb could result in reduced payloads, hence reduced revenues, at the extreme international ranges. At the New York-Paris distance, for example, the payload reduction with a 2.0/1.5 pound profile would be approximately 17,500 pounds, a 41 percent decrease from the payload possible with a 2.5/1.7 pound profile.

Several comments may be made in qualitatively evaluating this potential revenue loss. First, payload is not affected by 2.0/1.5 pound restrictions for route distances less than 3300 statute miles. Second, boom restrictions are less probable on eastbound international departures from the U.S., where overwater climb is possible. Third, for the westbound European departures, the airlines would probably trade-off this potential loss in revenues against the increased costs of abnormal flight procedures. A quantitative assessment of this effect will be made in subsequent analyses.

A4.3 THE ECONOMICS OF SONIC BOOM

In order to assess the magnitudes of the costs of boom damage and of abnormal flight procedures, let us consider the following hypothetical examples:

Case A — 52 major U.S. city-pairs

Case B — 18 city-pairs selected from Case A so as to represent the principal markets

Case C — 32 city-pairs selected from Case A so as to minimize costs of boom damage.

The 52 city-pairs considered were separated by distances ranging from 910 statute miles (Washington, D.C.-Miami) to 3340 statute miles (New York-Anchorage). Each case was considered under the following conditions:

a. Flight frequencies for SST service at the same level as September, 1964 jet service.

b. Population corresponding to the Census projection for 1975, and including Canadian population where overflown.

[redacted]

c. SST design corresponding to Boeing November 1, 1964 submission.

d. With each of the three IDA claims cost estimating procedures (person-boom, best judgment, and person-day).

e. With each of three dollar values per claim ($200, $60, and $20). IDA derived the $60 per claim by statistical analysis of the Oklahoma City tests. The range $20 to $200 per claim was suggested to IDA by casualty insurance firms with whom they consulted.

In their report, IDA considered the 52 U.S. city-pair example (Case A) using the $60 per claim figure and the Boeing January 15, 1964 design. In subsequent work, IDA prepared the additional three examples. The results for Case A are listed in Table A4.1; for Case B, in Table A4.2; and for Case C, in Table A4.3. The most striking results are:

a. the wide range of variation in estimates of costs attributable to sonic boom. For Case A, the expected total cost (column 8) is $69.2 millions, with a range of $25.2 to $446.0 millions. It is questionable whether SST service would continue to be offered if actual costs approached the upper limit of this range. For Case B, the corresponding total cost is $62.5 millions, with a range of $15.3 to $355.0 millions; for Case C, $28.1 millions, with a range of $8.7 to $78.0 millions. This highlights the uncertainty in estimation, and the need for more and better data on the economic effects of boom.

b. only a few city-pairs (New York-Los Angeles, New York-San Francisco, and Washington, D.C.-Los Angeles) account for a major part of both the damage and the SST market.

Turning now to Free World routes outside the United States, we note that abnormal procedures may be used more effectively there than on the domestic routes. Again using September 1964 flight frequencies, IDA categorized 86 major foreign routes as follows:

Degree of boom problem	Daily airplane route mileage	Percent total mileage
None	153,160	18
Minimal	158,530	19
Intermediate	424,558	50
Maximal	108,997	13
	845,245	100

In determining the degree of boom problem existing over a given foreign route, IDA considered the following factors:

a. Number of people boomed via great circle route.

b. Ease of avoiding population by abnormal procedures.

c. Type of ground structures subjected to boom overpressures.

Extreme Restriction

As a final example, we considered the extreme restriction of SST operations:

a. Political restriction of SST operations to city-pairs separated by water.

b. A supersonic transport design sufficiently economic in operation and attractive to the traveler to

Table A4.1. Annual Sonic Boom Costs for Case A (52 Major U.S. City-Pairs)

(1)			(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)
IDA theory			Claims cost[1]			Normal[2] operating costs (Million $)	Sonic boom costs (Million $)	Reduction[3] through circuity and subsonic operations (Million $)	Sonic boom costs subtotal (Million $)	Added[4] operating costs caused by abnormal operations (Million $)	Total costs attributable to sonic boom (6) + (7) (Million $)	Percentage addition to "normal" operating costs
Person boom	"Best judg-ment"	Person day	$200/ claim	$60/ claim	$20/ claim							
X			X			$1,117	$666.0	$231.0	$435.0	$11.0	$446.0	40.0%
	X		X			1,117	346.0	151.0	195.0	11.0	206.0	18.5
		X	X			1,117	267.0	125.0	142.0	11.0	153.0	13.7
X				X		1,117	199.9	69.3	130.6	11.0	141.6	12.7
	X			X		1,117	103.5	45.3	58.2	11.0	69.2	6.2
		X		X		1,117	80.0	37.4	42.6	11.0	53.6	4.8
X					X	1,117	66.6	23.1	43.5	11.0	54.5	4.9
	X				X	1,117	34.6	15.1	19.5	11.0	30.5	2.7
		X			X	1,117	26.7	12.5	14.2	11.0	25.2	2.3

[1] The $20-$200 range represents the limits suggested to IDA by various agencies consulted. IDA used the $60 claims cost in its calculations.

[2] "Normal" operating costs are annual total operating costs for the Boeing 733-290, the costs calculated according to FAA Phase IIA operating costs for that aircraft.

[3] The cost reductions assume route changes and subsonic operations as indicated in IDA's seven route configurations for lessening boom effects, pp. 39-52 of the IDA report.

[4] Added operating costs are based on the combined circuity and subsonic operations for route configurations 2-8 as outlined in the IDA report, pp. 39-52.

[redacted]

Table A4.2. Annual Sonic Boom Costs for Case B (18 Principal U.S. City-Pairs)[1]

(1) IDA theory			(2) Claims cost			(3)	(4)	(5)	(6)	(7)	(8)	(9)
Person boom	"Best judg-ment"	Person day	$200/ claim	$60/ claim	$20/ claim	Normal[2] operating costs (Million $)	Sonic boom costs (Million $)	Reduction[3] through circuity and subsonic operations (Million $)	Sonic boom costs subtotal (Million $)	Added[4] operating costs caused by abnormal operations (Million $)	Total costs attributable to sonic boom (6) + (7) (Million $)	Percentage addition to "normal" operating costs
X			X			$815.0	$523.0	$178.0	$345.0	$10.0	$355.0	43.6%
	X		X			815.0	232.0	57.0	175.0	10.0	185.0	22.7
		X	X			815.0	152.9	37.9	115.0	10.0	125.0	15.4
X				X		815.0	157.0	53.5	103.5	10.0	113.5	13.9
	X			X		815.0	69.5	17.0	52.5	10.0	62.5	7.7
		X		X		815.0	45.8	11.3	34.5	10.0	44.5	5.5
X					X	815.0	52.3	17.8	34.5	10.0	44.5	5.5
	X				X	815.0	23.2	5.7[5]	17.5	10.0	23.2[5]	2.8
		X			X	815.0	15.3	3.8[5]	11.5	10.0	15.3[5]	1.9

[1] Routes include 18 city-pairs that account for 72 percent of the flight frequencies in Case A, the 52 city-pair basic IDA model. The cities served include New York City, Boston, Philadelphia, Washington, D.C., Miami, Cleveland, Chicago, New Orleans, Houston, Dallas, St. Louis, Los Angeles, San Francisco, and Seattle.

[2] "Normal" operating costs are annual total operating costs for the Boeing 733-290, the costs calculated according to FAA Phase IIA operating costs for that aircraft.

[3] The cost reductions assume route changes and subsonic operations for the appropriate city-pairs, as indicated in IDA's seven route reconfigurations for lessening boom effects, pp. 39-52 of the IDA report. Routes involving 13 of the 18 city-pairs are changed with circuity or limited subsonic operations.

[4] Added operating costs are based on the combined circuity and subsonic operations for those routes involved in the 18 city-pair case.

[5] The added operating costs are greater than the cost reduction through circuity and subsonic operations. From a cost standpoint, it would pay to fly the "normal" profiles.

[redacted]

Table A4.3. Annual Sonic Boom Costs for Case C (32 U.S. City-Pairs)[1]

(1)			(2)			(3)	(4)	(5)	(6)	(7)	(8)	(9)
IDA theory			Claims cost			Normal[2] operating costs (Million $)	Sonic boom costs (Million $)	Reduction[3] through circuity and subsonic operations (Million $)	Sonic boom costs subtotal (Million $)	Added[4] operating costs caused by abnormal operations (Million $)	Total costs attributable to sonic boom (6) + (7) (Million $)	Percentage addition to "normal" operating costs
Person boom	"Best judg-ment"	Person day	$200/ claim	$60/ claim	$20/ claim							
X			X			$367.0	$113.6	$36.6	$77.0	$1.0	$78.0	21.2%
	X		X			367.0	157.1	66.6	90.5	1.0	91.5	24.9
		X	X			367.0	162.1	69.0	93.1	1.0	94.1	25.6
X				X		367.0	34.1	11.0	23.1	1.0	24.1	6.6
	X			X		367.0	47.2	20.1	27.1	1.0	28.1	7.7
		X		X		367.0	48.6	20.7	27.9	1.0	28.9	7.9
X					X	367.0	11.4	3.7	7.7	1.0	8.7	2.4
	X				X	367.0	15.7	6.6	9.1	1.0	10.1	2.8
		X			X	367.0	16.2	6.9	9.3	1.0	10.3	2.8

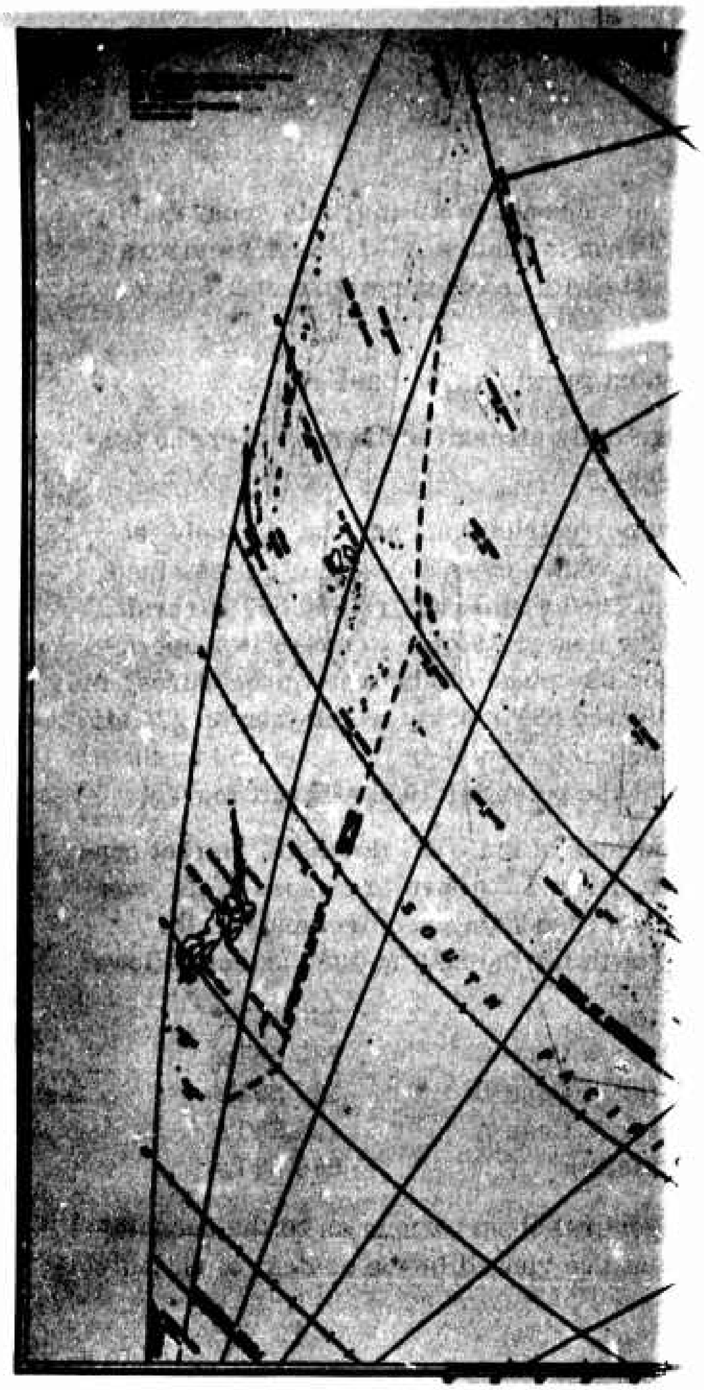
[1] Routes include 32 city-pairs of the basic 52 city-pairs used by IDA in the basic model (Case A). The 32 city-pairs were selected on the basis of minimizing boom costs, i.e., operating among cities where such routes would tend to avoid population. The 32 city-pairs account for 37 percent of the flight frequencies in Case A. Twenty-five cities are served, but with minor exceptions (e.g., San Francisco-Boston) the major-transcontinental routes are omitted. Three city-pairs (New York-Miami, Los Angeles-Dallas, and Los Angeles-Houston) appear in both Cases B and C.

[2] "Normal" operating costs are annual total operating costs for the Boeing 733-290, the costs calculated according to FAA Phase IIA operating costs for that aircraft.

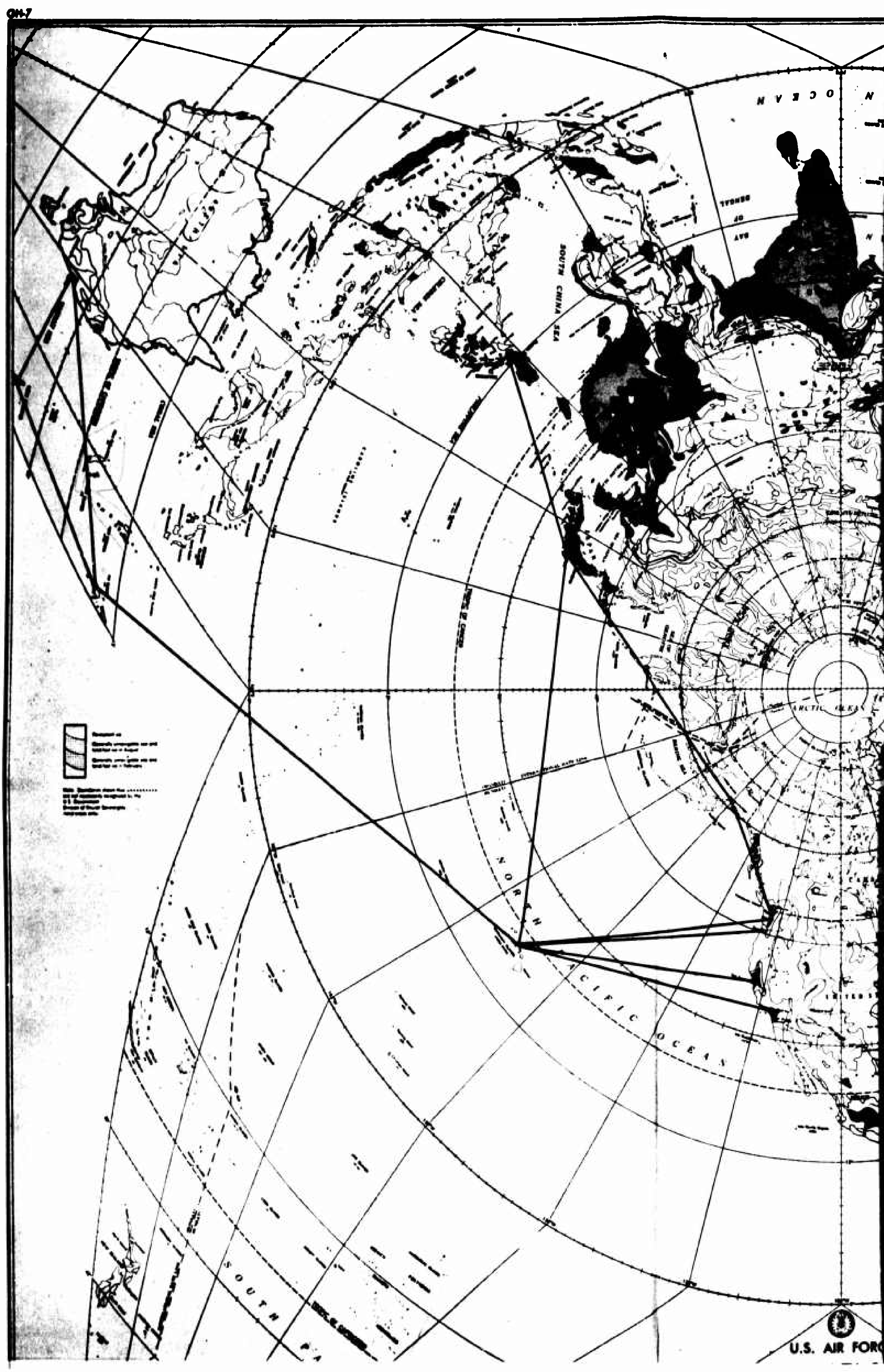
[3] The cost reductions assume route changes and subsonic operations for the appropriate city-pairs. Routes involving 13 of the 32 city-pairs are affected.

[4] Added operating costs are based on the combined circuity and subsonic operations for those routes involved in the 32 city-pair cases.

Miami - New York
London - New York
Honolulu - Los Angeles
Manila - Tokyo
Paris - New York
Honolulu - San Francisco
Anchorage - Seattle
Madrid - New York
Tokyo - Honolulu
Nandi - Sydney
Nandi - Honolulu
Caracas - New York
Tokyo - Anchorage
Dakar - London
Honolulu - Seattle
San Juan - New York
New York - Shannon
Boston - London
Madrid - San Juan
Honolulu - Portland
Shannon - Boston
San Juan - Miami
Mexico City - Miami
Miami - Boston
New Orleans - Mexico City
San Juan - New Orleans
Sydney - Auckland
Caracas - Miami
San Juan - Philadelphia
San Juan - Boston
Nandi - Auckland
London - Washington
Paris - Washington
Dakar - Rio de Janeiro
Mexico City - Lima
San Juan - Washington



A



SOUTH CHINA SEA
BAY OF BENGAL
ARCTIC OCEAN
NORTH PACIFIC OCEAN
SOUTH PA
U.S. AIR FORC

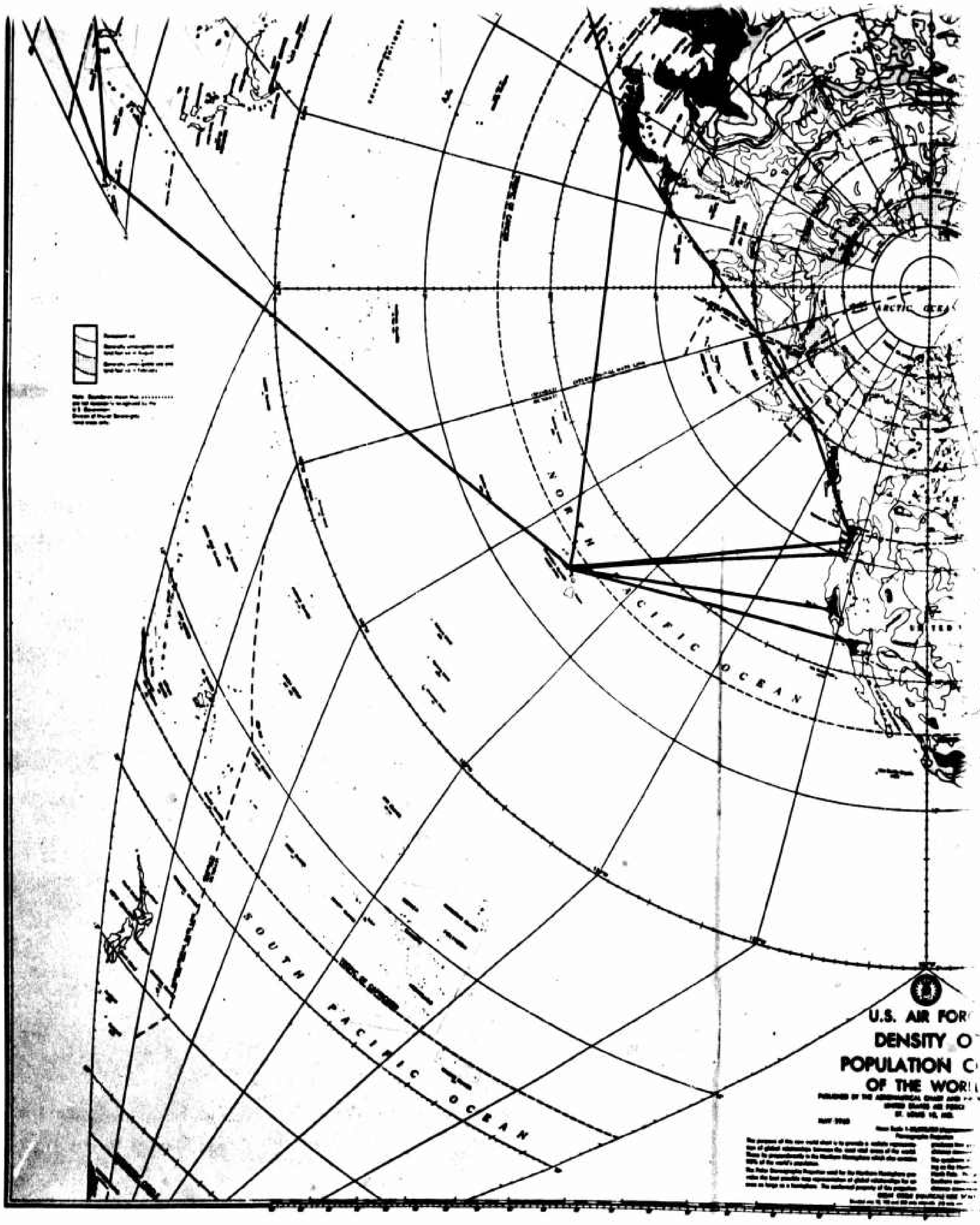
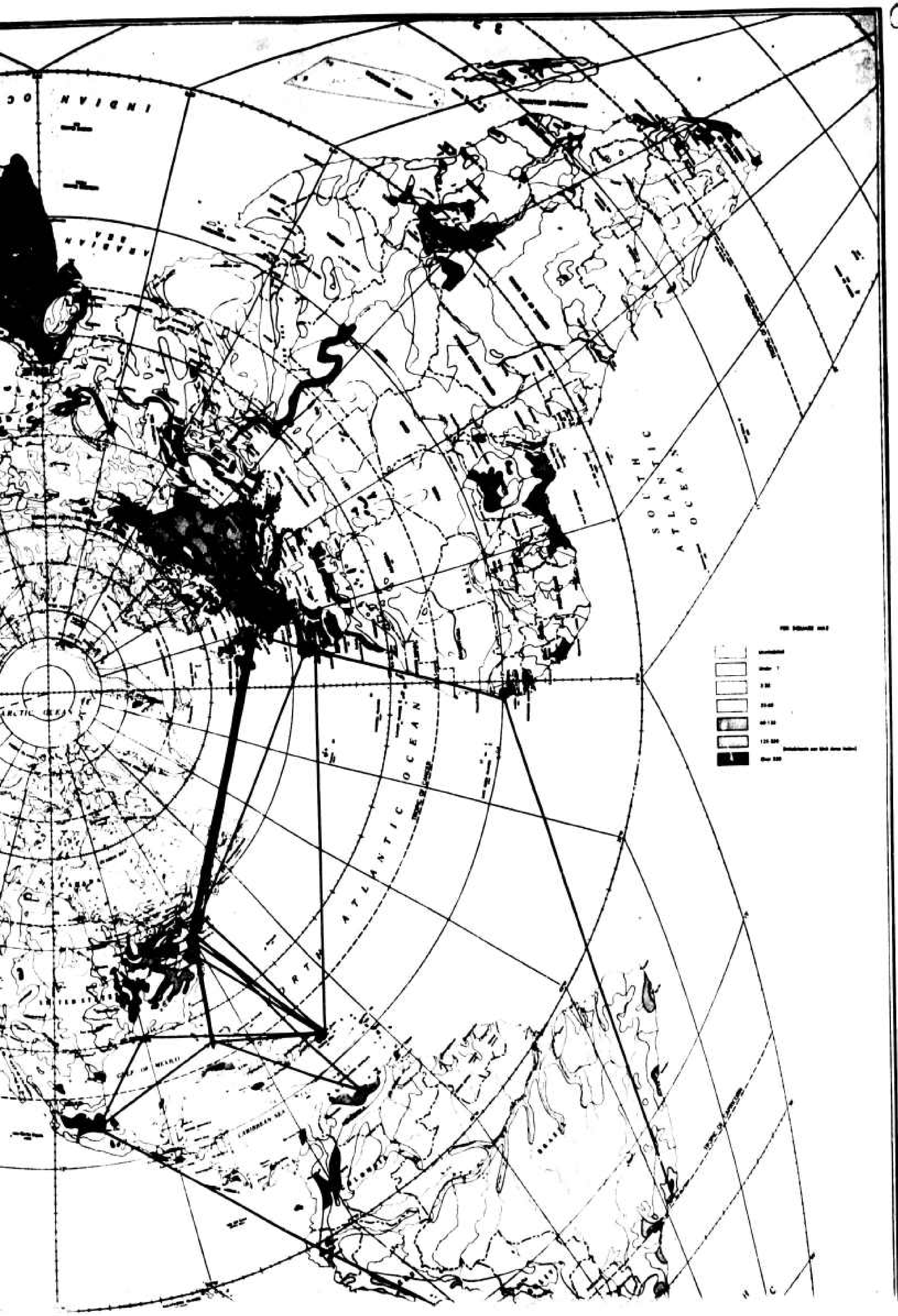
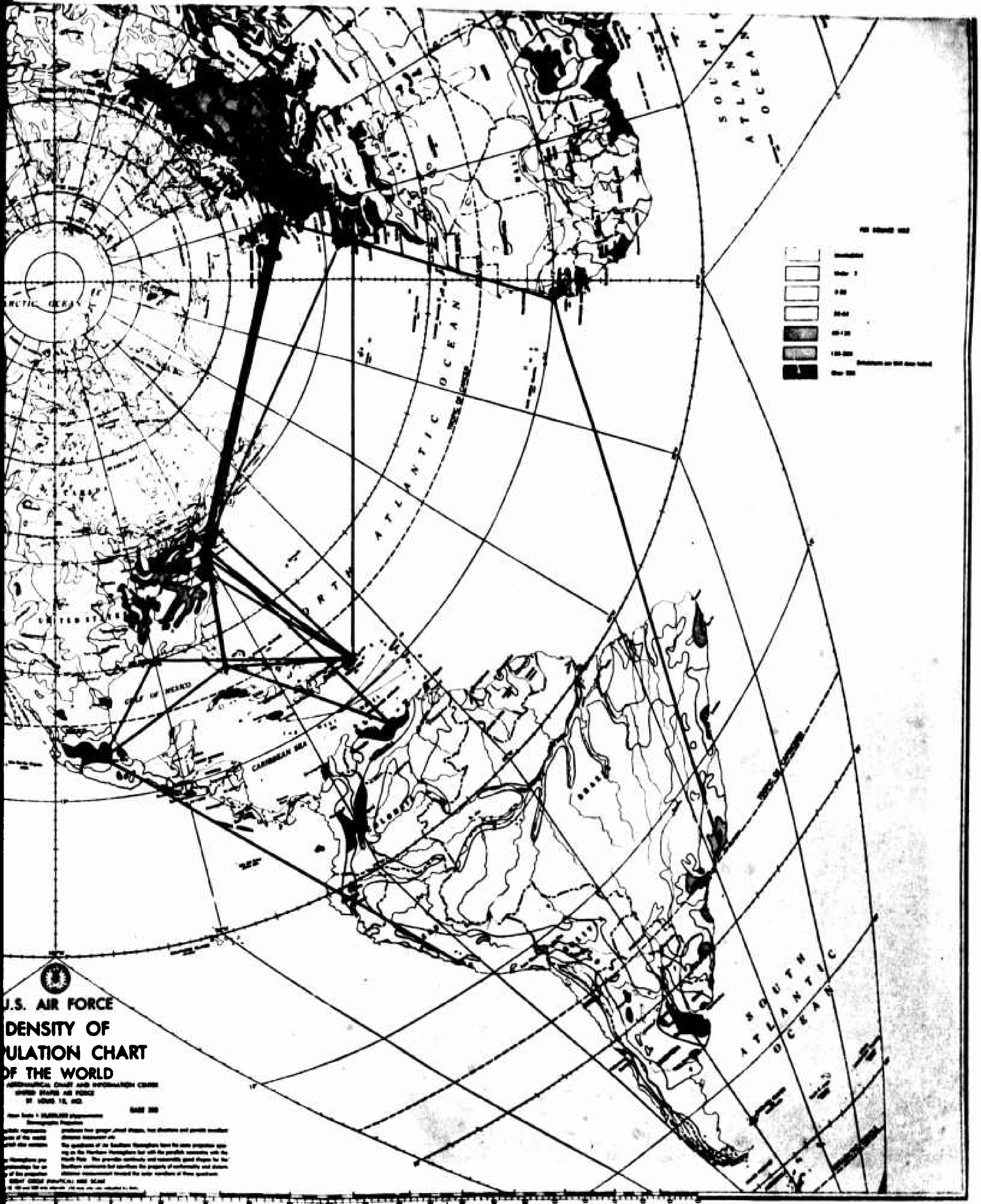


Figure A4.1. Case V.

[redacted]



INDIAN OC
ARABIAN SEA
SOUTH ATLANTIC OCEAN
ATLANTIC OCEAN


U.S. AIR FORCE
DENSITY OF
ULATION CHART
OF THE WORLD
NORTH ATLANTIC OCEAN
SOUTH ATLANTIC OCEAN
CARIBBEAN SEA
GULF OF MEXICO
ARCTIC OCEAN
BRAZIL

displace the subsonic in all markets separated by water as shown in Figure A4.1. Such an aircraft could operate with an overpressure of 2.5/1.7 pounds.

c. Air transport growth at the base rate.

d. An average daily aircraft utilization over the system of 9 hours.

If there were no restrictions, and the subsonic jet were displaced in all routes over 900 statute miles, the projected market in 1980 would require 660 SST aircraft. If the same SST were now restricted to overwater operations and only minor use made of abnormal procedures, the corresponding projected SST market would then be 220 aircraft. This extreme case results in the retention by the SST of 33 percent of the potential 1980 aircraft market.

When the fractions of the U.S. domestic market considered in Cases A, B, and C above are added to the overwater market, the corresponding requirements at the expected rate of growth for the SST in 1980 are as follows:

Overwater	220 SSTs
Overwater + Case C	285 SSTs
Overwater + Case B	367 SSTs
Overwater + Case A	424 SSTs
No restriction	660 SSTs

When these general observations as to the economic significance of boom are viewed in the context of an individual airline, the problem of boom may increase. Depending on the geographic distribution of the routes of an individual airline, its management may find it costly to operate the SST. Although it was not possible within the time frame of this study to explore this problem on an individual airline basis, we propose to do so in our subsequent analyses.

A4.4 SUMMARY

The economic effects of sonic boom are such as to increase the costs of operation and, possibly, to reduce revenues through loss of payload and/or markets. On the extreme assumption that the SST is restricted to overwater operations, the hard core requirement for aircraft expected in 1980 is 220 SSTs, within a range of 170 to 290. This market can then be expanded up to 660 aircraft (the expected market if boom effects were negligible) depending on the respective willingness of:

a. the carriers to incur the additional costs associated with boom so as to increase their revenues. These costs over U.S. domestic routes are expected to amount to 7 percent of total operating costs, within a range of 2 to 40 percent,

b. the general public to accept higher ambient noise levels.

The wide range in expected additional costs highlights the need for more engineering work to minimize boom generation and more study of socio-political reactions to boom.

[redacted]

A5. SST PROGRAM FINANCING

The purposes of this section are:

a. To summarize projections of the ability of aircraft manufacturers and airlines to finance the SST development and production costs;

b. To compare these financial abilities with corresponding requirements for development, production and purchase of the SST; and

c. To discuss, within the limits of financial ability, corporate incentives and willingness to share the risks in the SST Program.

A5.1 INTRODUCTION

Financially, for the four participants—manufacturers of airframes and engines, U.S. and foreign airlines, lenders, and the Government—the SST project must be regarded as an equation of risks and possible rewards. On one side, there are substantial risks, involving a minimum of \$1.2 billion for development and approximately \$29 million[1] per plane in production thereafter. On the other side, the rewards may be:

a. for the manufacturers: sales of approximately \$6 billion (initial outlay for aircraft) for a moderately successful market of 200 planes, and \$12 billion for a more successful program of 400 planes. To these must be added the substantial sales of initial and maintenance spare parts.

b. for the airlines: the stimulus of a completely new generation of planes able to transit the country in approximately 2 hours, and the Atlantic in 3 hours.

c. for the Government: the retention of American leadership in civil aircraft over foreign manufacturers, the accompanying balance of payments benefit, and technological fall-out.

d. for institutional lenders: contribution to the growth of the airline industry, and participation in the profits.

By its own evaluation of the degrees of uncertainty and risk, versus the possible rewards, each of the participants will decide how far and on what terms it can and may wish to commit resources.

The financing of the SST in its various phases depends first on the financial requirements of the SST project, and second on the following factors:

a. The financial ability of manufacturers and airlines—defined as their total financial resources available for the SST.

b. The willingness of manufacturers and airlines to invest, within their financial ability, in the SST.

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[1]Based on FAA estimates, including development cost allocated over a market of 200 planes, and excluding spares. If allocated over 600 planes, the total cost per plane drops to \$25 million.

c. Within the same framework, the financial ability and willingness of financial markets to finance SST requirements of manufacturers and airlines; and

d. Any residual amount, not met by the combination of the above 3 factors, which must be supplied through Government assistance if there is to be an SST Program.

The focus on risk-taking is crucial to the financial analysis of the SST Program, and must be viewed on a time-phased basis. Given a competitive design at this time, there remain technological, economic, and market uncertainties greater by far than those experienced with past subsonic planes. These uncertainties have been discussed earlier in the summary, Section 6.2. Illustrative of past risks are the grounding of the postwar Constellation and DC-6 planes, the failure of the Rainbow design of Republic Aircraft, the costly design error in the Electra, and the vast losses in the Convair 880/990 planes. Each of these vehicles was a direct lineal descendant of known and tried planes in military and/or civilian service at subsonic speeds. In the SST, by contrast, we are dealing with novel metals, sealants, mechanical components and systems which exist largely in the laboratory, on design boards and in a few test operations. There are no precedents for operation at supersonic speeds for the sustained utilization of 3,000 to 4,500 hours per year characteristic of commercial transports.

In terms of financial commitments, the decision points for risk-taking (illustrative rather than definitive) are these:

1965: (1) Go ahead with development at some specified pace.

(2) One versus two competitive prototypes.

(3) Financing and management plan, allocating costs and responsibilities among manufacturers, airlines and Government.

1968-9: (1) Determination of prototype success after 100 hours of flight.

(2) If there are competitive prototypes, either selection of one producer, or decision to advance with competing producers. The latter occurs if both prototypes are very good and the market will sustain two.

(3) Firm commitment of airlines to choice of planes, with progress payments thereafter.

(4) Full-scale production tooling.

1972: (1) Certification by FAA; plus possible additional in-service testing.[1]

(2) Further commitment to plane orders by airlines.

1972-3: First planes in service under the present FAA schedule.

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[1]The suggestion has been made in an engineering subcommittee of NASA that the SST be subjected to as much as 7,500 hours of flight testing before carrying passengers. Under alternative assumptions, certification could occur in 1974-5.

1972-7: First, and critical, 5-year service period during which airlines and manufacturers learn where they stand with the SST. For operators, this is the period of highest transition costs and risk-taking, but substantially offset by probable high load factors due to wide gap between competition-dictated demand and relatively low supply rate.

Because of the high degree of uncertainty, the period 1965-9 is the most difficult and critical for financing. It may involve design and development outlays on the order of $746 to $1,773 million dollars, depending on whether there are one or two competing prototypes. Moreover, it is the period when manufacturers and airlines have the least financial ability and willingness to take risks. Upon completion of 100 hours of prototype testing however, the airlines will have been at the plane controls in flight, and thus in a better position to make a firm decision as to whether to commit themselves to orders and progress payments, subject to specification warranties.

A decision fundamental to risk-taking and the pace of financial requirements pivots on the question of whether to proceed conservatively toward prototype testing with the minimal investment in tooling; or whether to invest in production tooling on the assumption that the possible gain in time (presumably, to reduce Concorde sales) warrants the heavier financial risks.

Who contributes the financing, and who makes the controlling decisions, are questions which go to the heart of the SST project, bearing heavily on the chances for its successful fulfillment.

A5.2 SST FINANCIAL REQUIREMENTS

The four sets of SST cost estimates used here are:

a. Costs as submitted by the manufacturers,

b. Those of the FAA validation team (designated hereafter as "FAA"),

c. Those of Operations Research Incorporated (ORI), and

d. Those of Planning Research Corporation (PRC).

The financial discussion of this chapter focuses primarily on the Boeing/GE proposal, referring to the Lockheed/United Aircraft Corporation (UAC) proposal only insofar as it is used in the discussion of competitive models. The FAA cost estimates are treated as nominal, PRC estimates as an upper limit. Table A5.1 compares the four sets of estimates for prototype and certification costs. For Boeing/GE and using FAA as 100 percent, manufacturers are low at 88 percent, ORI is middle at 119 percent and PRC is high at 133 percent. For Lockheed/UAC and FAA as 100 percent, the manufacturers are 132 percent, ORI is 117 percent, and PRC is again high at 141 percent.

The Boeing/GE prototype SST, with minimal tooling and 100 hours of flight, may require $746 million. Competitive prototypes, including the Lockheed/UAC plane on the same basis, may require $1,773 million.

From 100 hours of prototype testing through FAA certification, during which substantial investment in production tooling must be made, another $446 million will be required for one producer, and $752 million for two competing producers.

Table A5.1. Development Costs for 100-Hour Prototype and Subsequent Certification
(million dollars)

Estimator	Stage	Boeing/GE			Lockheed/UAC			Two versions
		Frame	Engine	Total	Frame	Engine	Total	
Manufacturers	Prototype	$ 450	$ 210	$ 660	$ 630	$ 680	$1,310	$1,970
	Certification	231	161	392	148	300	448	840
	Total	681	371	1,052	778	980	1,758	2,810
FAA	Prototype	490	256	746	715	312	1,027	1,773
	Certification	252	194	446	168	138	306	752
	Total	742	450	1,192	883	450	1,333	2,525
PRC	Prototype	588	398	986	701	701	1,402	2,388
	Certification	302	302	604	164	309	473	1,077
	Total	890	700	1,590	865	1,010	1,875	3,465
ORI	Prototype	701	205	906	850	357	1,207	2,113
	Certification	359	155	514	200	158	358	872
	Total	1,060	360	1,420	1,050	515	1,565	2,985

[redacted]

Through certification, therefore, the aggregate financial need is for $1.2 billion for one producer, and $2.5 billion for two producers. This would be increased moderately if non-revenue service testing up to 7,500 hours were undertaken.

Production of planes for delivery to airlines involves a working capital requirement. The total amount will depend on the production rate per month and the length of time between commencement of production and delivery to the airlines. The peak production requirement (FAA) for a 200 plane market occurs in 1973, the second year of delivery to airlines, and is $714 million.[1]

Transitional costs to airlines for initial training and break-in are estimated at $1.0 to 2.0 million per plane.

A5.3 SOURCES OF SST FUNDS: GENERAL

The normal historical pattern of financial participation by manufacturers and airlines may require substantial modification in view of the higher risks and financial requirements of the SST development and production.

The Normal Pattern

The normal pattern has proceeded along the following lines:

a. Design and development have been undertaken and financed entirely out of the manufacturer's internally generated cash resources.

b. In the production phase, fixed investment in facilities has been financed by the manufacturer by a combination of internally generated cash and sale of stock or debt.

c. The production pipeline has been treated as a working capital requirement financed by the manufacturer through a combination of its own resources, airline advance payments, the excess, if any, of accounts payable over receivables, and revolving bank credits.

d. The manufacturer in the past has usually been helped by having a military prototype closely related to his commercial offshoot—an advantage absent in the case of the SST.

The Possible SST Pattern

The SST pattern of financing can depart from the above normal pattern along a combination of the following lines:

a. Potential airline customers, U.S. and foreign, may participate substantially in the financing of the design and development stage;

b. Airlines may also make heavier advance payments to manufacturers in the production stage;

c. Government may aid in the development and production stages by loans, grants, or the equivalents;

d. Subcontractors may participate, in one form or another, in the financing of production and development stages.

Table A5.2 compares normal patterns of financing with possible future SST patterns. In evaluating these possible deviations from the normal pattern, it is posited

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[1]A tabulation of production requirements by years will be found in Table A5.17.

Table A5.2. Usual Subsonic and Possible SST Patterns of Financing[1]

Phase	Manufacturer		Airlines		Lenders		Direct U.S. Gov't. aid, for SST beyond Phase IIA	
	Subsonic	SST	Subsonic	SST	Subsonic	SST	Subsonic	SST
100-Hour prototype	v	v	O	P	O	O	O	P
Certification	v	v	v[2]	v[2]	O	O	O	P
Production facilities	v	v	O	O	v	v	O	P
Production working capital	v	v	v[2]	v[2]	v	v	O	O
Purchase — U.S. airlines	O[3]	O[3]	v	v	v	v	O	O
Foreign airlines	O[3]	O[3]	v	v	v	v	v[5]	v[5]
Operation	O[4]	O[4]	v	v	O	O	O	O

[1]"v" means yes for the past or yes/likely for the SST; "O" means no for the past or no/likely for the SST; and "P" means possible.
[2]In the form of advance payments subject to specifications warranty.
[3]Occasionally, but not usually, by partial financing or leasing through credit subsidiaries of manufacturers.
[4]Only in extraordinary event such as the Electra modification.
[5]By Eximbank.

here that the best approach would seek to preserve the normal buyer-seller relationship between airlines and manufacturers. This means that the key decisions as to technology, nncing and economics would be worked out between them, and remain their responsibility. A corollary is that the major financial inputs should also come from between them. Contrariwise, it means that the Government role in making these decisions can and should be ancillary, and that the Government should not directly contribute a major part of funds required for development. It is axiomatic that the power of the purse cannot be separated from the responsibility for decisions. If the Government contributes the major financing, it must, to protect its interest, reserve the right to make the controlling decisions.

Projections of Financial Ability

To determine the ability of private enterprise to share SST risks, projections have been made of the balance sheets and operating statements of the four manufacturers immediately involved, and of the domestic trunklines. For the manufacturers, these consist of a "base projection" (with a

[redacted]

high and low range for key items to indicate uncertainty), made to 1975 to cover the initial delivery years of the SST.

For U.S. airlines, projections have been made to 1980, in order to include not only the prototype and certification stages of development, but also the first years of commercial use. Three sets of projections have been made, designated "base," "high" and "low." With different sets of assumptions as to traffic growth and earnings, these are intended to encompass a reasonable range of possible events. The focus here is on the base projections, considered the most likely to prevail, with a note on the range of high and low for significant items. A more detailed discussion, and full tabular data for the three sets of projections will be found in Part II. It should be noted that the projections exclude the SST. This makes it possible to superimpose or substitute SST finances according to various assumptions that may be desired.

Because of the effective control of most foreign airlines by their governments, it is neither meaningful nor useful to make financial projections for them. As in the case of American carriers, however, whether from competitive necessity or favorable economics, foreign airlines will be customers for the SST. It is therefore possible that they will share the incentives of American carriers to contribute to the development stages of the SST. A comprehensive study of the past financial history of individual foreign carriers is included in Part III.

Cash Flow Items:

The principal sources of cash are:

a. Earnings before taxes,

b. Depreciation,

c. Decreases in working capital,

d. New debt,

e. Stock sales,

f. Sale of property, and

g. Deferred taxes.

The uses of this cash are chiefly:

a. Taxes on earnings,

b. Plant, property and equipment (PPE),

c. Increases in working capital,

d. Cash dividends,

e. Reduction in debt, and

f. Stock repurchases.

Regarding these factors, certain simplifying and reciprocal relationships exist which have been incorporated into the projections:

a. Since corporate taxes of 48 percent are after expenses, it is useful to define the "upper limit" of financial ability as being before taxes.

b. Expenditures for PPE are continued at the rates required to maintain and expand the airlines operations during the critical pre-delivery stages. Once deliveries of the SST have begun, substitution would take place in the proportion of SST requirements to the total.

c. Cash dividends, and changes in debt and stock outstanding, are interchangeable and offer important alternatives for corporate policy (i.e., the less cash dividends paid out, the less need be the sales

[redacted]

[redacted]

of debt or stock). Only net changes in these items are shown in cash flow projections.

d. Working capital requirements are normally related to the scale of business. They are often abnormally high due to irregular and temporary influxes of cash in connection with debt and stock operations, or abnormally low due to heavy capital expenditures before planned receipt of new funds from debt or stock. In the projections, however, they have been kept at the normal relationship.

e. Sales of property are expected to occur at salvage value in the case of airlines. As they will be special and irregular events constituting a small fraction of cash generated, they are noted rather than included in the formal projections.

f. Deferred taxes, which are a bookkeeping arrangement rather than a true cash item, are assumed to hold constant in the case of the airlines, with accruals on new property offsetting expirations on previously acquired equipment. Therefore, they do not show up in the cash flow projections.

With these simplifying relationships, the ability of a company to contribute to SST financing in the various stages of the program may be reasonably expressed in terms of a few key items of cash flow. The sources of cash are earnings (before and after taxes), depreciation, and net new capital issues (whether in debt or sales of stock). The uses of cash are for investments in PPE, dividends, and net changes in working capital.

Range of Financial Ability

The range of financial ability to contribute to the financing of the SST in the various stages may be defined in terms of four patterns, or policy alternatives, available to corporate managements, schematized in Table A5.3. These are as follows:

a. Normal, after cash dividends and Federal income taxes, which is taken as the lower limit of financial ability.

b. Normal with a cash dividend constraint, taken for the purposes of this study as no increase in cash dividends above the current rates (as of February, 1965).

c. The upper limit, with the same dividend constraint, but including earnings before taxes.

d. The upper limit, with zero cash dividend payout, also including earnings before taxes.

The constraint on cash dividends can be fully compensated by the substitution of dividends in stock.

Each of the four patterns has some pragmatic basis in experience, and therefore the limits represent a useful range of financial ability for the SST. Thus, it is not unusual for corporate managements, faced with heavy capital requirements, to limit cash dividends. There are numerous instances generally (and including aircraft manufacturers and airlines) where cash dividends have been kept abnormally low, or at zero, with or without compensating payments of stock dividends.

A5.4 SOURCES OF SST FUNDS: MANUFACTURERS

The post-war financial histories of the airframe and engine manufacturers have been so erratic as to provide little statistical basis for projections to 1975. The projections of this report are therefore based on a combination of

[redacted]

Table A5.3. Limits of Airline Cash Flow for SST: Treatment of Principal Variables

Pattern	In			Out			
	Earnings re tax		Depreciation	PPE	Cash dividends[1]	Working capital
	Before	After				
1. Normal		X	X	X	X	X
2. Normal with cash dividend constraint		X	X	X	1965 level	X
3. Upper limit with cash dividend constraint	X		X	X	1965 level	X
4. Upper limit	X		X	X	None except in stock	X

[1]Plus dividends in stock as desired, which conserve cash and have substantial tax advantages for the stockholder.

qualitative analysis of past corporate financial data, conferences with DOD as to the outlook for the military budget and the possible participation of individual companies, and searching discussions on a proprietary confidential basis with the companies involved. All projections for the manufacturers have been made by the SST staff. Our projections may be considered useful as approximations of what may occur, and are essential for the rational evaluation of the SST project.

The projections are averages for the years 1965-75. The range given each projection is also useful as an index of the uncertainty. Profits are taken as a percent of sales rather than on investment because of the historically high, though now decreasing, ratio of Government-owned property used by aircraft manufacturers, and in this respect are conservative.

The projections do not assume the superimposition of the SST Program. During the prototype stage, a company would divert an important but indeterminate part of its managerial and financial resources into the program. This displacement of other non-SST programs could become very substantial when the company enters the production stage.

Boeing

Table A5.4 shows the historical pattern (1950-1964) for the principal items entering into cash flow. Table A5.5 summarizes the projections of cash flow for 1965-75, with 1964 shown as a reference.

a. Sales: These are projected at an average of \$1.8 billion dollars annually, plus or minus 20 percent, through 1975. This is approximately the level for 1961-4, up from \$287 million in 1949.

[redacted]

Table A5.4. Boeing Company, Significant Cash Flow Items, 1950-64
(million $)

Year	Sales	Earnings after tax	Depreciation and amortization	Cash dividends	Additions to PPE	Year end	
						L.T. debt	Working capital
1950	307	10.8	0.8	3.2	2.9		46
1951	337	7.1	1.2	3.2	5.2		46
1952	732	12.4	1.6	4.3	6.7		49
1953	913	18.3	2.8	5.7	8.0		57
1954	1,072	33.5	4.9	9.7	5.2		82
1955	905	28.6	5.8	10.6	7.6		98
1956	1,096	35.4	7.1	8.2	31.2		101
1957	1,674	39.8	12.9	6.7	45.6		102
1958	1,752	30.2	19.1	7.0	19.5	71	197
1959	1,649	12.7	19.5	7.4	18.1	71	204
1960	1,555	24.5	19.4	9.1	17.4	71	199
1961	1,801	35.7	20.6	13.5	26.8	65	178
1962	1,769	27.2	21.0	16.0	50.1	115	196
1963	1,771	21.7	21.6	16.0	28.2	115	243
1964[1]	1,900	42.0	23.0	16.0	33.0	110	

[1]Estimated.

[redacted]

[redacted]

Table A5.5. Boeing Company—Projections of Annual Cash Flow, 1965-75 (without the SST), with 1964 for Reference (million $)

Item	Estimated 1964	Projections	
		Amount	Range
1. Sales	$1,900	$1,800	± 20%
Sources			
2. Earnings before Federal income taxes	84	69[1]	± 40%
3. Depreciation and amortization	23	24	
4. Net sales of debt or equity		0[2]	± 40%[3]
5. Total		93	
Uses			
6. Federal income taxes (48% projected)	42	33	
7. Cash dividends (50% of net after taxes projected)	16	18	
8. PPE (additions to plant property and equipment)	33	30	
9. Net change in working capital requirement		0	
10. Total		81	
Net cash available for SST annually			
1. Normal pattern		12	
2. Normal with 1965 dividend rate		14	
3. Upper limit, earnings before taxes, 1965 dividend rate		47	
4. Upper limit, earnings before taxes, no dividends		63	

[1]Earnings after taxes are projected at 2% of sales.
[2]Not significant, with stock options estimated at $10 million for the period 1965-75, and with debt roughly constant.
[3]For debt.

[redacted]

b. Profits (after taxes): These are projected to average 2 percent of sales, or $36 million annually, with a range of plus or minus 40 percent. Over the past 10 years, Boeing's return on sales has fluctuated widely from 0.8 percent in 1959 to 3.5 percent in 1955 and 1956. For 1961-2-3, it experienced 2.0, 1.5, and 1.2 percent, respectively. For 1964, it is estimated at 2.2 percent, due partly to the completion of pre-production write-offs on current commercial aircraft.

c. Depreciation and amortization: The annual provision has been rising steadily (due to the increase in company-owned, as against Government-owned, property) from $4.9 million in 1954 to $23 million in 1964. Depreciation is projected at an average of $24 million annually for 1965-75.

d. Sales of debt and stock: Positing a continuation of the present level of sales, the existing capital stock structure of 8.0 million shares would normally be maintained, except for stock options. The options amount to possibly 2-1/2 percent, or approximately $10 million, and therefore may be ignored. Due to their uncertain fortunes, the aircraft manufacturers have an ingrained tendency to minimize the use of long-term debt. Currently for Boeing, this is $110 million, and may vary in the future by 40 percent up or down. Given the great uncertainties of the SST in the prototype stage, and the historical pattern of financing development expenses from within the company's own resources, it is unlikely that debt would be increased for the SST in this stage. Working capital for actual production against firm orders will be provided from the company's own funds, airline payments, and through revolving short-term bank credits.

e. Uses of cash generated:

1) Dividends, which are currently $16 million a year, are projected at 50 percent of earnings or $18 million. This is on the assumption that near-term earnings (1965-7) are expected to increase because of completion of the write-off of past jet development expense, together with continuing commercial sales of 707 and 727 jets.

2) Additions to property, plant and equipment, which have increased from $5 million to $28 million between 1954 and 1963, and to $33 million in 1964, are projected at $30 million.

3) Net long-term debt is assumed to average the present $110 million, and therefore no net repayment is projected. As noted above, however, a variation of plus or minus 40 percent is considered possible.

4) Working capital, with sales projected at current levels, is also assumed not to change.

f. Net cash available for SST project: Under the normal pattern, cash available after taxes, dividends and PPE additions would average $12 million for the years 1965-75. Holding dividends at the current rate would raise this to $14 million. Before Federal income taxes, and current dividends, SST availability becomes $47 million. The upper limit, before taxes and with zero dividends, is $63 million. For the crucial prototype stage of 1965-9, the aggregate availability on these four bases would be 60, 70, 235, and 315 million dollars, respectively.

Lockheed

With some differences of detail, the projections for Lockheed are based on the same methodology and combination of sources used for Boeing. Cash flow items for 1950-64 are given in Table A5.6. The derivation of financial availability is given in Table A5.7.

a. Sales: The annual average projected for 1965-75 is $1.75 billion, plus or minus 10 percent. With the exception of 1954-6, sales rose in every year from $174 million in 1950 to a peak of $1,930 million in 1963. For 1964, they are estimated at approximately $1,625 million.

b. Profits: These are projected at 2 percent of sales or $35 million per year, with a range of variation of 10 percent either way. They have been within this range during the years 1961-3, but are estimated at 2.7 percent in 1964.

c. Depreciation and amortization: This account has risen from $1.3 million in 1950 to $19 million in 1964. It is projected at an average of $23 million per year.

d. Sales of debt and stock: With the projected continuation of the current level of sales, the existing capital structure is likely to be maintained except for stock options. If the total existing authorization were taken up, approximately 6 percent would be added to the shares outstanding, with a value in the neighborhood of $20 million. Long term debt at year end 1964 is $23 million, and being extinguished at a required rate of $1.75 million a year. The company could undoubtedly increase its debt for purposes normally considered appropriate, but probably not for the high risk prototype development of the SST. It would appear reasonable to assume that cash from exercise of stock options may be approximately offset by cash used for debt redemption, without a net change in cash position.

e. Uses of cash generated:

1) Dividends are projected at a yearly average of $23 million. This is at the new rate of $2.00 per share declared February 1, 1965, an increase from $1.60, plus an allowance for increase in stock through exercise of options and conversions from debt.

2) Additions to PPE, which have increased steadily from $4 million in 1950 to $30 million in 1964, are projected at an average of $35 million per year.

3) Long term debt is assumed to be reduced in accordance with the indenture by $1.75 million annually (but see Item d above).

4) Working capital is continued at the current levels, consistent with the assumption of an unchanged sales level.

f. Net cash available for SST project: Under the normal patterns, cash available after taxes, dividends and PPE additions would average zero. Before taxes, availability is $32 million with cash dividend payout, and $55 million without any dividend payout.

United Aircraft Corporation (Pratt & Whitney)

For 1965-75, the normal pattern of cash generated from earnings and depreciation is projected at a stand-off

[redacted]

Table A5.6. Lockheed Aircraft Corporation, Significant Cash Flow Items, 1950-64
(million $)

Year	Sales	Earnings after tax	Depreciation and amortization	Cash dividends	Additions to PPE	Year end	
						L.T. debt	Working capital
1950	174	7.3	1.3	3.3	3.7		28
1951	239	5.9	1.8	2.5	8.0		32
1952	442	9.2	2.9	2.8	6.2		36
1953	820	14.4	3.8	4.9	6.2		43
1954	733	20.5	4.7	7.2	7.5		53
1955	676	16.5	5.8	8.5	15.5	30	85
1956	751	15.3	8.2	6.8	22.0	58	110
1957	879	16.6	10.8	7.1	18.9	58	108
1958	975	18.8	12.3	7.2	15.3	48	107
1959	1,304	8.7	13.1	8.0	21.5	41	76
1960	1,332	-42.9	14.3	2.2	18.0	40	58
1961	1,445	26.1	15.1	4.6	24.6	33	81
1962	1,753	37.2	16.5	9.4	29.1	28	120
1963	1,931	43.3	16.9	13.9	27.5	25	140
1964[1]	1,625	44.0	19.0	17.0	30.0	23	157

[1]Estimated.

[redacted]

Table A5.7. Lockheed Aircraft Corporation—Projections of Annual Cash Flow, 1965-75 (without the SST), with 1964 for Reference (million $)

Item	Estimated 1964	Projections	
		Amount	Range
1. Sales	$1,625	$1,750	± 10%
Sources			
2. Earnings before Federal income taxes	82	67[1]	± 10%
3. Depreciation and amortization	19	23	
4. Net sales of debt or equity		0[2]	
5. Total		90	
Uses			
6. Federal income taxes (48% projected)	38	32	
7. Cash dividends	17	23	
8. PPE (additions to plant property and equipment)	30	35	
9. Net change in working capital requirement		0	
10. Total		90	
Net cash available for SST annually			
1. Normal pattern		0	
2. Normal with 1965 dividend rate		0	
3. Upper limit, earnings before taxes, 1965 dividend rate		32	
4. Upper limit, earnings before taxes, no dividends		55	

[1]Earnings after taxes are projected at 2% of sales.
[2]Stock options realized are assumed to offset reduction in debt.

with uses. Cash flow for 1950-64 is shown in Table A5.8; projections for 1965-75 are shown in Table A5.9.

a. Sales: These are projected at $1.2 billion, compared with the same level in 1964 and an historical peak of $1.28 billion in 1963.

b. Profits: The Company's earnings have been characterized by wide year-to-year swings. They are projected at 2 percent of sales, or $24 million a year. This compares with 2.3 percent in 1964, 1.7 percent in 1963, and 1.6 percent in 1962.

c. Depreciation and amortization: This rose from $14 million in 1954 to $30 million in 1960-2, and $34 million in 1964. It is projected at $37 million.

d. Sales of debt and stock: Based on an analysis of the debt structure and stock options policy, a simplifying assumption is made that the net reduction of long term debt will be just offset by an equal amount of funds from exercise of options.

e. Uses of cash generated:

1) Dividends are projected at the rate of $15 million a year (with allowance for exercise of stock options but not for optional conversion of convertible debentures). This assumes continuance of the current rate of $2 per share.

2) Additions to PPE: This was $50 million in 1964 which is also the projection for 1965-75.

3) Long term debt reduction is assumed to be offset by exercise of stock options (see Item d above).

4) Working capital is continued at present levels in line with sales.

f. Net cash available for SST project: Under the normal pattern, sources and uses are approximately equal. Before tax, the surplus would be $22 million. If dividends were foregone for the sake of investment in the SST prototype the upper limit of availability would be $37 million a year.

General Electric Company

This company cannot be appraised like Boeing, Lockheed and United Aircraft. Its sales in 1964 were approximately $5 billion, of which the Flight Propulsion Division amounted to $500 million.

The company's normal earnings in 1964 were $312 million after taxes.[1] With depreciation and amortization at $129 million, total cash thus generated was $441 million. Before taxes, this rises to about $730 million for the year. Although GE can fully underwrite the financing of the SST prototype engine, the SST is only one of the many projects which must compete for available resources. In terms of risk and profitability, GE management is likely to evaluate its financial contributions to the SST prototype along the same general lines as the more specialized airframe and engine manufacturers. Against the attractiveness and risks of the SST Program, management will weigh the internal competitive demands for available funds and managerial resources.

In the absence of separate financial data for GE's Flight Propulsion Division, a simplified projection of SST

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[1]These earnings are before special "price adjustments," completed in 1964, resulting from an antitrust case, which distort the current and future earnings picture. With these adjustments, earnings become $237 million after taxes.

[redacted]

Table A5.8. United Aircraft Corporation, Significant Cash Flow Items, 1950-64
(million $)

Year	Sales	Earnings after tax	Depreciation and amortization	Cash dividends	Additions to PPE	Year end	
						L. T. debt	Working capital
1950	269	13.2	9.9	6.6	6.4		90
1951	417	14.3	7.0	7.7	22.6		81
1952	668	17.8	11.6	7.7	33.8		68
1953	818	21.2	14.7	10.0	13.2		80
1954	654	26.0	13.7	12.5	19.0		75
1955	698	31.1	17.0	14.5	20.1		89
1956	953	37.1	19.4	15.7	22.1		138
1957	1,233	51.4	18.9	17.9	49.8		141
1958	1,200	42.3	23.4	20.4	35.8		148
1959	1,081	28.6	28.5	17.4	23.1		162
1960	988	13.9	30.0	14.5	35.9	50	202
1961	1,095	10.0	30.0	14.2	33.0	75	209
1962	1,160	18.1	30.5	14.2	37.5	75	207
1963	1,281	21.4	30.8	14.2	49.3	118	244
1964[1]	1,200	28.0	34.0	14.4	50.0	115	250

[1]Estimated.

[redacted]

Table A5.9. United Aircraft Corporation—Projections of Annual Cash Flow, 1965-75 (without the SST), with 1964 for Reference (million $)

Item	Estimated 1964	Projections	
		Amount	Range
1. Sales	$1,200	$1,200	± 15%
Sources			
2. Earnings before Federal income taxes	52	46	± 20%
3. Depreciation and amortization	34	37	
4. Net sales of debt or equity		4	
5. Total		87	
Uses			
6. Federal income taxes (48% projected)	24	22	
7. Cash dividends	14	15	
8. PPE (additions to plant property and equipment)	50	50	
9. Net change in working capital requirement		0	
10. Total		87	
Net cash available for SST annually			
1. Normal pattern		0	
2. Normal with 1965 dividend rate		0	
3. Upper limit, earnings before taxes, 1965 dividend rate		22	
4. Upper limit, earnings before taxes, no dividends		37	

[redacted]

financial availability for that Division has been made on the basis of approximately $500 million annual volume of business. This has been done by taking other financial items in the same proportion to United Aircraft's projection, as their annual sales. The derivation is shown in Table A5.10. Earnings and depreciation approximately equal cash dividends and PPE, as constructed by the UAC analogue, leaving no availability under the normal patterns. Before taxes, the availability becomes $9 million, and without any cash dividend payouts it rises to $15 million a year. These amounts represent a very small part of the cash available to GE.

A5.5 SOURCES OF SST FUNDS: U.S. CARRIERS

In the past, airlines have contributed little or nothing to financing of prototype developments. Their contributions have been during the production stage, in the form of progress payments of one-fourth to one-third of the purchase price.

Any expenditures made by the airlines on the SST Program may be classified, (1) as those which are historically normal, consisting of progress payments during the production cycle and final payments upon delivery, and (2) as those extraordinary payments which might be made during the prototype, certification, and production stages. These latter payments must come from resources over and above those required for the expansion in flight equipment to meet expected growth in traffic, before SST deliveries.

To determine the limits of financial ability of airlines with regard to the SST, two sets of projections of their finances have been made—one for the aggregate of 13 U.S. trunklines in domestic and overseas service, and the other for each of five potential SST-using trunklines: Pan

Table A5.10. General Electric Company[1]—Projections of Annual Cash Flow, 1965-75 (without the SST)

Flight Propulsion Division

Item	Million dollars
1. Sales	500
Sources	
2. Earnings before Federal income taxes	19
3. Depreciation and amortization	16
4. Net sales of debt or equity	—
5. Total	35
Uses	
6. Federal income taxes (48% projected)	9
7. Cash dividends	6
8. PPE (additions to plant property and equipment)	20
9. Net change in working capital requirement	0
10. Total	35
Net cash available for SST annually	
1. Normal pattern	0
2. Normal with 1965 dividend rate	0
3. Upper limit, earnings before taxes, 1965 dividend rate	9
4. Upper limit, earnings before taxes, no dividends	15

[1]Projected from UAC detail in proportion of sales of GE to UAC.

American, TWA, American, United and Northwest. National has been included in an abbreviated projection to obtain some insight into a principal Florida trunkline. The airlines included in the projections are listed in Table A5.11.

The studies of the individual airlines have two purposes: (1) to provide a basis for analysis and derivation of individual airline patterns, and (2) to provide a comparison and calibration with the aggregate trunkline projections.

Time Periods. The projections for the 13 trunkline aggregates and for the individual six were made through 1980. This takes them through the important initial years of operating the SST.

Methodology. The methodology is summarized here, and set out in detail in Part II. The financial projections are made entirely on the basis of subsonic operations and without provision for the SST. The funds required for the SST can then be superimposed on, or substituted for, those for the large subsonic jets.

Assumptions. The fundamental assumptions underlying the financial projections involve rate of traffic growth, load factors, and the rate of return. Others are the revenue yield per passenger-mile or freight ton-mile, the dividend payout, and the interest rate on debt. The assumptions, shown in Table A5.12, are based on a qualitative evaluation of trends of airline traffic in relation to the economy, evaluation of past studies and projections, and discussions with market projection staffs and financial officers of aircraft manufacturers, airlines and the CAB.

The three sets of assumptions are common to all the financial projections presented, aggregate and individual. They are also compatible, as to growth rates of traffic, with SST market projections. The base set of assumptions is intended to represent the expected pattern; the high and low, a range of possible variation.

Table A5.11. Trunk Airlines Included in Financial Projections

Airline	Projection set	
	Aggregate	Individual
1. American	X	X
2. National	X	X
3. Northwest	X	X
4. Pan American	X	X
5. TWA	X	X
6. United	X	X
7. Braniff	X	
8. Continental	X	
9. Delta	X	
10. Eastern	X[1]	
11. Northeast	X	
12. Panagra	X	
13. Western	X	

[1]Eastern was not included in program of individual financial projections because of heavy losses in recent years, amounting to $37 million in 1963, which would unduly complicate the projections of near-years, and limit their usefulness. In order to gain an insight into the Florida market, National with its more normal financial pattern of recent years was included. The discussion is here limited to the aggregate of the Five airlines, not including National.

Table A5.12. Assumptions for Airline Financial Projections (without SST)

Item	Base	Low	High
1. Growth in passenger-miles,			
% yearly, International . .	10	8	12
Domestic	7-1/2	5-1/2	9-1/2
2. Rate of return on investment,			
% yearly.	10	5	12
3. Interest on debt, %.	5	5	5
4. Revenue per passenger-mile		OPEN[1]	
5. Dividend payout		OPEN[1]	
6. Growth in freight, express			
and mail.		OPEN[1]	
7. Load factors		OPEN[1]	

[1]Left to judgment of individual airlines or the CAB.

Cooperative Procedure in Making Calculations

In the autumn of 1963, the CAB made aggregate projections for 1963-8 on a single set of assumptions which were somewhat different from those of the SST economic staff. These were accepted as usable estimates when modified for known results for 1963-4. Projections for 1969-80 embodying assumptions developed by the SST economic staff were then computed by the CAB staff. These latter assumptions had first been critically reviewed with the CAB and the six airlines individually.

The assumptions as to growth in passenger traffic, rate of return, and interest rate were uniform for all six airlines. Each airline was given leeway, according to its own experience and financial patterns, as to growth of freight traffic, load factors, dividend payouts, and revenue yields per passenger mile. The SST economic staff is responsible for the key assumptions and therefore for the projections. The individual airlines have cooperated in discussing the assumptions, in running out the calculations, and in bestowing upon them the intimate knowledge of detail on which only they can be authoritative.

Traffic Growth—Passenger Miles

For domestic U.S. traffic, the projection on the base assumption is for an average growth rate of 7.5 percent to 1980. This compares with average growth rates for 1955-64, 1960-4, 1961-4, 1962-4, and 1963-4 of, respectively, 9.0, 9.3, 12.3, 14.5, and 14.9 percent. The high and low growth rates for domestic passenger traffic are two percentage points on either side of the base, or 9.5 and 5.5 percent.

For international traffic of U.S. carriers, the base rate of growth is projected as an average 10 percent a year. This compares with average growth rates for 1955-64, 1960-4, 1961-4, 1962-4, and 1963-4 of 13.4, 14.6, 17.5, 18.8, and 20.0 percent, respectively. Again, the high and low growth rates are two percentage points on either side of the base, or 8 and 12 percent.

The projections of traffic growth as a basis for financial projections differ in several details from, but are compatible with, those made for the SST market in Section A2 of this report:

a. The financial projections refer to U.S. carriers, while the SST demand projections are for the entire Free World.

b. The financial projections were based on the separate growth rates of domestic and international traffic, while the SST market is based on an aggregate calculation.

c. The financial projections use an average growth rate over the period 1965-80, while the SST market grows at a slowly declining rate. An average growth rate is used to simplify the calculations.

Traffic Growth—Non-Passenger

The combination of freight, express, mail and excess baggage has amounted to approximately 9 percent of total domestic trunk airline revenues in recent years, and about a fifth for U.S. international carriers. Their individual growth rate assumptions were left to CAB and the cooperating airlines, and are discussed in Part II.

Load Factors

Given the growth rates of traffic and the equipment utilization (such as nine hours per day), the primary variable determining acquisitions of new flight equipment is the load factor. Here again, the base, low and high assumptions were discussed with, but left to, the cooperating airlines and CAB.

Rate of Return

The average rate of return on investment allowed to domestic and international airlines by the CAB ranges between 10.25 and 10.5 percent, approximately the rate being earned currently (1964-5). This rate is likely to continue until the advent of an SST generation of planes. For financial projections without the SST, a base rate of 10 percent has been used. For the low set of assumptions, a 5 percent return was used. While the CAB would normally not permit an average return of 12 percent over an extended period of time, this was used as an upper limit in order to provide for special conditions which might arise in the near term.

Fares, Revenues and Expenses

These three items are residual and complementary once the rate of return is specified. The yield per passenger-mile is the result of nominal fares, and the proportions of tourist, excursion, and first-class travel. In order to maintain a given rate of return, the three items can mix in various proportions.

Interest Rate

These were projected uniformly at 5 percent on debt as an approximation of current and foreseeable conditions.

Trends

The dimensions of the growth of U.S. airlines through the period of initial operation of the SST (but without the SST superimposed) may be gained from the projected trends of key balance sheet and operating statement items shown in Table A5.13. Total assets, less current liabilities, are projected to increase from $3.3 billion in 1964 to $8.2 billion in 1980; operating revenues, from $3.8 billion in 1964 to $11.5 billion in 1980; earnings after taxes, from $75 million in 1963 and $208 million in 1964 to $586 million in 1980; depreciation, from $345 million in 1964 to $1,123 million in 1980.

Relative Importance of Cash Flow Items

Projections of the cash flow of the 13 U.S. trunklines may be limited to the six principal items. The sources are earnings, depreciation, and debt; the uses of cash are PPE, dividends and the relatively small item of increases in working capital. Debt is the balance wheel, once the other five

items are fixed. Stock sales are indeterminate and irregular in the airlines business. The calling of convertible debentures when the market price is at a premium (as is the probable case under the base set of assumptions) results in the reduction of debt and a reciprocal increase in net worth. At the end of 1964, such convertibles amounted to $223 million. This was 14 percent of total long-term debt, and 8 percent of combined net worth and debt. For the most part, however, maturity dates generally extend beyond 1979, as may be seen from Table A5.14.

Airline Debt Ratios

The normal debt ratio (to debt plus equity) for the trunk airlines is generally accepted as 50 percent.[1] For the individual airline, depending on its fortunes at the time, it has varied from 100 percent (there have also been cases of negative equity) to almost zero. Since, in the financial projections, debt has been the residual factor, it has been determined after satisfying requirements for cash dividends, PPE and working capital for expanded operations. Therefore, the availability of cash for the SST in the pre-delivery stages under the normal pattern would always be zero. A basic assumption made here is that where the projected debt ratio in 1965-9 is less than 50 percent, it has been raised to 50 percent, with the resulting cash considered as available for the SST. For the period 1970-4, it has been raised to 55 percent for the reasons discussed below. It should be noted that during the subsonic jet transition, the debt ratio of the thirteen trunklines rose to 66 percent in 1961, from a post-war low of 28 percent in 1954.

[1]The CAB, for example, bases its rates of return on a 50 percent debt ratio. See its General Passenger Fare Investigation, Docket 8008, November 25, 1960, p. 32.

Table A5.13. Trend of Financial Projections, 1964-1980
13 U.S. Trunklines
(million $)

Item	1964[2]	1970	1975	1980
1. Total assets[1]	3317	3739	5516	8174
2. Operating revenues	3769	5120	7683	11515
3. Earnings after tax .	208[3]	271	397	586
4. Depreciation.	345	498	748	1123

[1]After deducting current liabilities. The projected ratio of revenues to assets averages 1.4, and represents an average historical relationship. The 1964 ratio of 1.1 arises largely from the heavy acquisition of the jet generation of planes, resulting in higher than average assets in relation to revenues.
[2]Estimated.
[3]Including $9 million of losses for EAL and NEA in 1964.

Limits of Airline Financial Ability

Based on the assumptions and conditions just outlined, the derivation and limits of airline financial ability to finance the SST are summarized for 13 trunklines in Table A5.15. They are shown as 5-year cumulative totals, with 1965-9 representing the prototype stage, 1970-4 representing certification, production, and initial operation stages, and 1975-9 an extension of the initial operating years for airlines. The corresponding detailed annual and historical tables will be found in Part II of this study.

Prototype Stage, 1965-9

The availability of cash for the SST Program under the four patterns is as follows:

a. Under the normal pattern, it is $590 million. This is after dividend payout of 50 percent of earnings after taxes, and after raising the debt ratio from 41 to 50 percent. It is assumed that the airlines will not go to higher debt ratios for the purpose of financing any part of the high-risk SST prototype stage.

b. By constraining dividend payout at the 1964-5 rate of $60 million a year, or $300 million for 1965-9, availability is increased by $177 million to $767 million.

c. This is further increased to $1,826 million by taking cash availability before Federal income taxes of $1,093 million.

Table A5.14. Maturity Dates of Convertible Securities, 13 Trunklines[1]

Period	Amount (million $)
1965-9	65
1970-4	2
1975-9	35
1980-4	121[2]
	223

[1]In addition, 2,700,000 warrants are outstanding to purchase TWA stock at $20 a share to June 1, 1965, and at $22 to December 1, 1973.

[2]$38 million of this amount has been called by TWA for redemption at March 30, 1965. At the same time, United Airlines is issuing $66 million of convertible debentures.

d. On the extreme assumption of zero dividend payout (which may occur under special circumstances), the upper limit of cash availability becomes $2,126 million.

Certification and Delivery Stage, 1970-4

Since the specific airplanes undergoing FAA certification must be from the regular production line, production overlaps the certification phase. While the certification and initial delivery date used here is July 1, 1972, it is also possible, under alternate FAA scheduling dates or retardation for other reasons, for this to occur as late as 1974-5. In projecting cash availability in this stage, therefore, full PPE requirements for non-SST purposes have been excluded. To the extent that SST planes were substituted for conventional jets in this period, however, that much PPE would be available for the SST Program in addition to the sums shown below. Because this period, as a combination of pre-delivery and initial delivery years, is normally characterized by peak capital requirements and elevated debt ratios, the normal pattern assumes, conservatively, a 55 percent debt ratio.

On this basis, the availability of cash for the SST is as follows:

1. Normal pattern (55 percent debt ratio) . $ 553 million
2. Normal with 1964-5 dividend rates . . . . $1,046 million
3. Upper limit, before taxes and with dividend constraint . . . . $2,511 million
4. Upper limit, with zero dividends . . . . . $2,811 million

[redacted]

Table A5.15. Cumulative 5-Year Cash Flows of 13 Trunklines, 1965-79, Base Assumptions (million $)

Item	1965-9	1970-4	1975-9
Sources			
1a. Earnings before taxes	$2,206	$3,051	$4,488
1b. Taxes	1,059	1,465	2,154
1c. Earnings after taxes	1,147	1,586	2,334
2. Depreciation	2,163	2,952	4,430
3. Net debt	-90	848	1,284
Total cash generation	$3,220	$5,386	$8,048
Uses			
4. PPE	$2,607	$4,400	$6,593
5. Dividends	477	793	1,167
6. Working capital	136	193	288
Total cash used	$3,220	$5,386	$8,048
7a. Debt ratio at end of period[1]	41.0%	44.6%	47.2%
7b. Additional cash by raising debt ratio to 50% in 1969 and 55% in 1974	590	553[2]	[3]

[1]Ratio of long term debt to sum of such debt and net worth.
[2]This amount is net of the $590 million obtained by raising the debt to 50% in 1965-9 and carried forward.
[3]The debt ratio is not raised beyond the carry-forward of $590 million and $553 million. The period 1975-9 would normally be past the initial peak acquisition of the SST, and therefore see a drawdown of the debt ratio.

Table A5.15. Continued

Item	1965-9	1970-4	1975-9
Net cash available for SST			
1. Normal pattern	590	553[4]	6,593[4]
2. Normal with 1965 dividend rate	767	1,046	7,460
3. Upper limit, with 1965 cash dividend rate	1,826	2,511	9,614
4. Upper limit, no cash dividends	2,126	2,811	9,914

[4]PPE is not excluded in 1975-9, as it is in the earlier stages, because there is a substitution of SST planes for conventional long-range jets. To the extent that SST deliveries may be made during 1972-4, PPE need not be, but has been deducted in those years, and therefore presents a conservative picture of cash availability. This also allows for the possible alternative time-phasing in which deliveries will not begin until 1974-5. Advance payments also reduce the draw on cash for PPE at delivery of planes.

Operating Stage, 1975-9

An essential difference between this and previous stages is that the item of PPE is now available on a substitution basis for SST planes. The four patterns of cash availability are as follows:

1. Normal pattern, including PPE . . . . . . $6,593 million
2. Normal, 1964-5 cash dividend rate. . . . $7,460 million
3. Upper limit, before taxes, and 1964-5 dividend rate . . . . $9,614 million

[redacted]

4. Upper limit, before taxes, and
   no cash dividends . . . . $9,914 million

While the above availabilities include the full amount of PPE, a large part will be required for non-SST planes and other uses.

Figure A5.1 presents net earnings (after taxes) for the 4 manufacturers and the 13 trunklines for the period 1950-1980.

Role of Foreign Airlines

Approximately 40 percent of the demand for an American-made SST is estimated to come from foreign airlines. Virtually all such carriers are wholly or substantially controlled by their governments. In the past, foreign carriers have bought U.S.-made planes, whether by choice or competitive necessity, by any of the following means, singly or in combination.

a. Their own resources, either internally generated, or from private borrowings or stock sales;

b. Government inputs in the form of grants, loans or stock purchases when the above proved inadequate;

c. Loans from the Export-Import Bank (and to a lesser extent, the World Bank), with a guarantee by the foreign government involved when required.

Part III of this report analyzes in detail the past patterns of financing by foreign airlines of purchases of American-made planes. In the future, if choice or competitive necessity requires foreign carriers to buy American SSTs, the most reasonable assumption is that the past patterns will continue, and that the SSTs will be bought. As to the direct role of the foreign carriers in the SST Program, purchases in the production stage would be financed in the normal manner. For the development stages, however, it is possible to envision plans under which foreign airlines might find it attractive to contribute to the financing in some form.

A5.6 SUMMARY OF REQUIREMENTS VERSUS ABILITY, AIRLINES AND MANUFACTURERS

Table A5.16 presents financing requirements versus the financial ability of the SST manufacturers and 13 trunklines for the prototype, pre-delivery, and delivery stages of the SST Program. The basic situation of one airframe and one engine manufacturer, with the totals for Boeing, GE, and the 13 trunklines, is shown, as well as the competitive situation including Lockheed and United Aircraft. These two situations are further developed in Figures A5.2 and A5.3. GE, as has been noted earlier, can finance the entire SST Program single-handed out of current earnings, but its finances have been analyzed only for the tenth of its operations represented by the propulsion division. The significance of pre-tax earnings ability differs between the manufacturers and the airlines. For the manufacturers, the bulk of expenses for development may be expensed currently, as this is their normal business. For the airlines, however, all payments to the manufacturer are normally regarded as capital investment. Nevertheless, the consideration of pre-tax earnings established a useful upper limit for the airlines as a tool of analysis of various possible financial plans.

Prototype Stage, 1965-9, Single Manufacturing Team

Against a combined frame and engine requirement of $746 million, the lower limit of availability, i.e., the normal pattern, is $650 million or 87 percent. With the 1965-dividend constraint, the availability would become $831

[redacted]

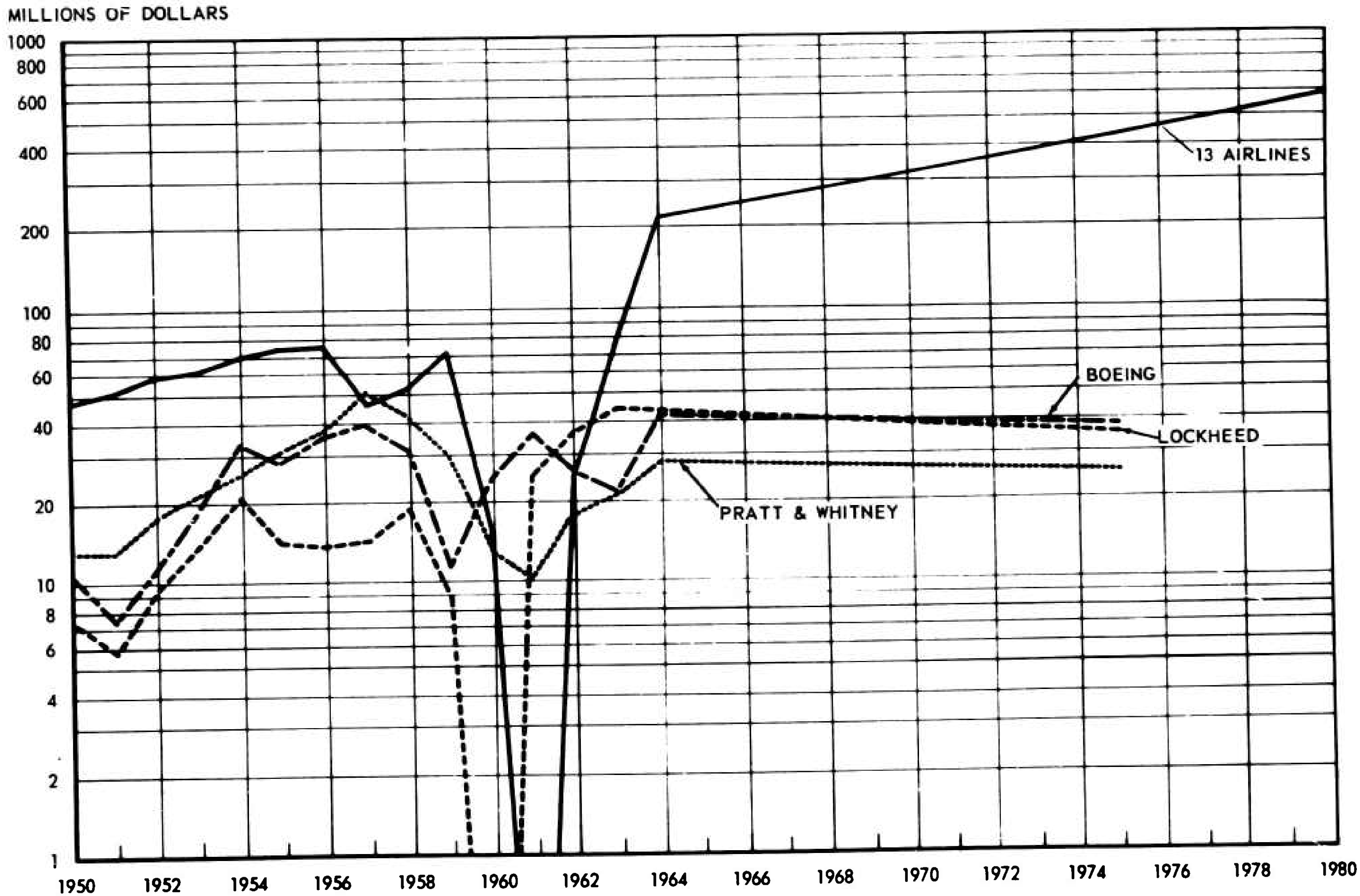


Figure A5.1. Net earnings (after tax) for manufacturers and thirteen trunklines (actual 1950–1964; projected 1965–1980).

[redacted]

[redacted]

Table A5.16. Financial Summary of SST Development Requirements (FAA and PRC) and Private Funds Availability, 1965-74, without SST (million $)

Period and pattern	One producer							Two competing producers					
	Development requirements			Financial ability[1]				Additional requirements			Additional ability		
	Total	Boeing	GE	Total	Boeing	GE[3]	13 Trunks	Total	Lockheed	UAC	Total	Lockheed	UAC
1965-9, Prototype: FAA	746	490	256					1,027	715	312			
PRC	986	588	398					1,402	701	701			
1. Normal				650	60	0	590				0	0	0
2. Normal with 1965 cash dividends . . .				837	70	0	767				0	0	0
3. Upper limit, 1965 cash dividends . . .				2,106	235	45	1,826				270	160	110
4. Upper limit, no cash dividends.				2,516	315	75	2,126				460	275	185
1970-4[2], FAA.	446	252	194					306	168	138			
PRC.	604	302	302					473	164	309			
1. Normal				613	60	0	553				0	0	0
2. Normal with 1965 dividends.				1,116	70	0	1,046				0	0	0
3. Upper limit, 1965 dividends.				2,791	235	45	2,511				270	160	110
4. Upper limit, no dividends.				3,201	315	75	2,811				460	275	185

[1]Additional sources may, under possible plans, be foreign airlines which place orders for the U.S.-made SST; and permissible charge-offs to military contracts of Research and Development and transition to civilian business.
[2]In this phase, 1970-2 is certification. 1973-4 is purely production. The requirement shown is for certification only.
[3]In the absence of other data, GE projections were made from the ratio of its sales from the Propulsion Division to sales of United Aircraft, applied to UAC totals.

[redacted]

[redacted]

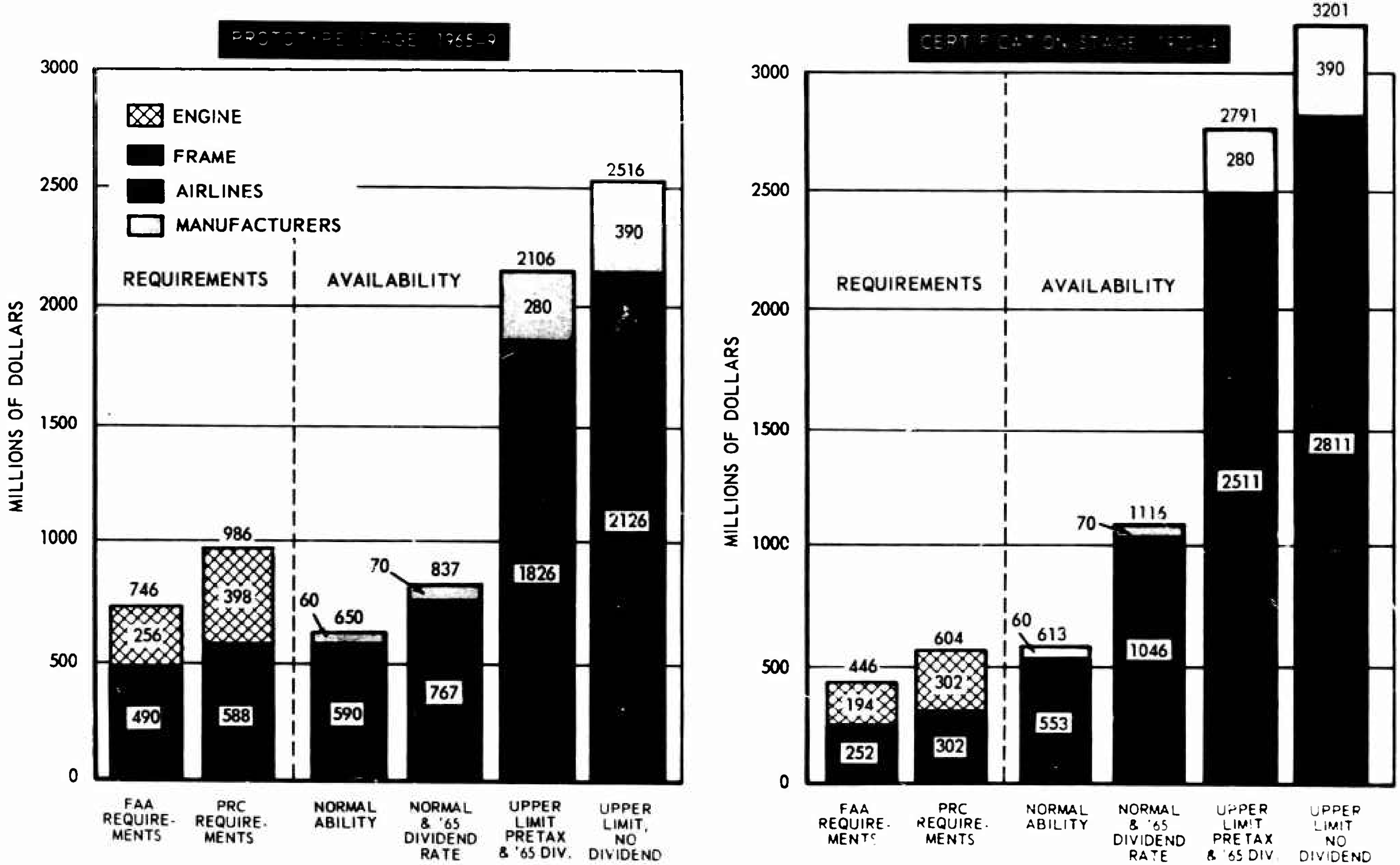


Figure A5.2. Projected SST requirements and financial ability (one producer).

[redacted]

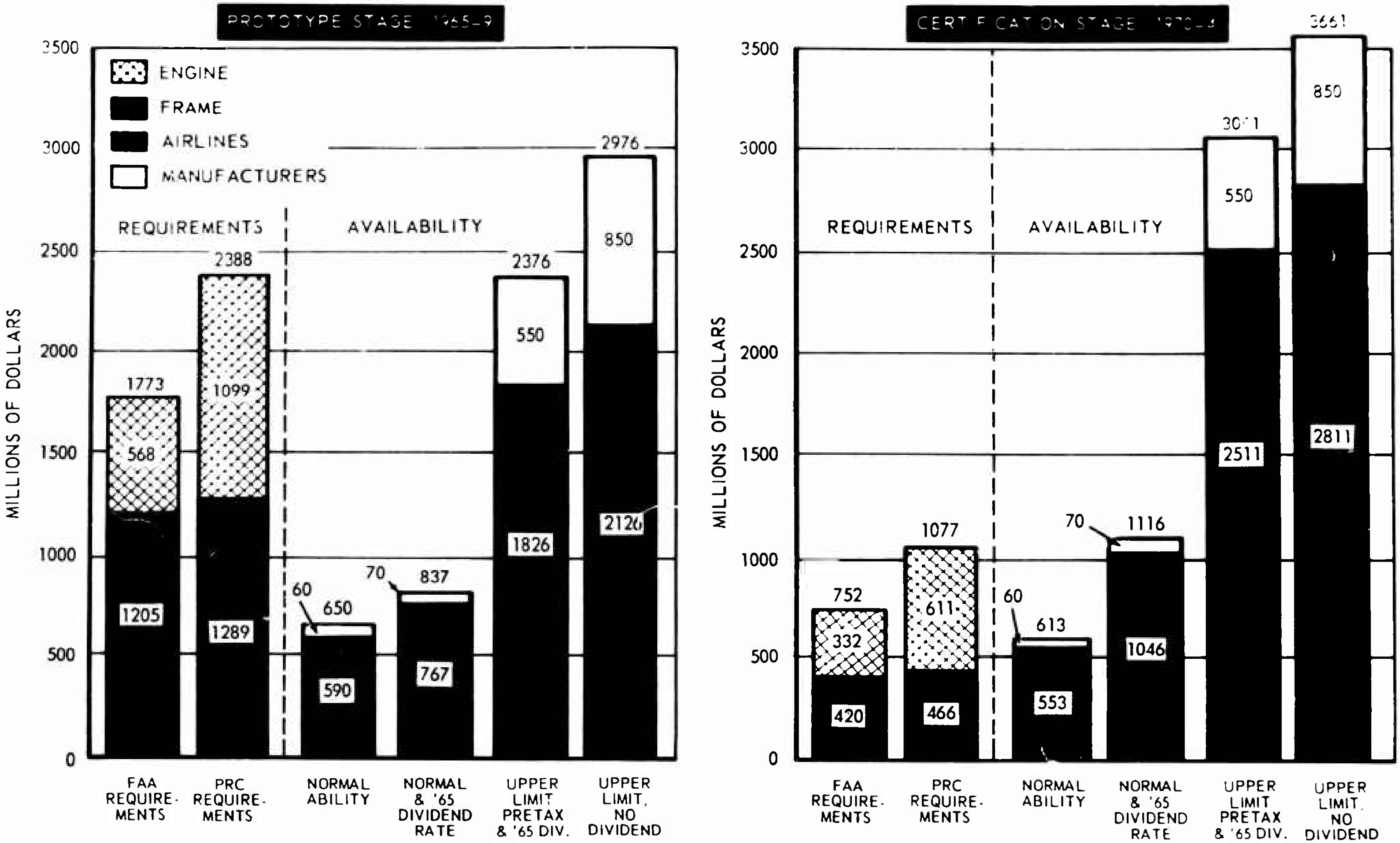


Figure A5.3. Projected SST requirements of financial ability (two competing producers).

million, or 112 percent of the requirement. The upper limits provide more than ample resources.

The greater part of ability is seen to come from the airlines. At the lower limit, Boeing could meet only 8 percent of the requirement, and 9 percent with the dividend constraint. At the upper limits, its ability is 32 and 42 percent, respectively. GE, if limited to the resources of the propulsion division and taken pro rata to United Aircraft (UAC) on the basis of sales, would have no availability under the normal patterns, and nominal ability of approximately 6 and 10 percent of requirement at the upper limits. The 13 airlines have a combined availability of 79 percent of the requirements under the normal pattern, and 103 percent with a dividend constraint. At the upper limits, their ability is again ample.

If the high costs of PRC are used, the prototype requirement rises to $986 million, from FAA's $746 million. While the normal pattern of ability, at $650 million, is too low to bridge this gap, the normal pattern with dividend constraint is $837 million, or 85 percent. This rises, before taxes, to $2,106 million.

Certification and Delivery Stage, 1970-4,
Single Manufacturing Team

Against a requirement of $446 million for certification, combined ability under the normal pattern is $613 million, or 137 percent of the requirement. Again, the ability rests largely with the 13 trunklines, with Boeing's ability only 13 percent of the requirement, and GE's nominally zero. With a dividend constraint, the normal ability is $1,116 million or 250 percent of the requirement. Boeing's is still only 16 percent, with GE's zero. At the upper limit with or without dividend constraint, the ability far exceeds the requirement. It is thus obvious that there is ample combined ability of airlines and manufacturers even at the lower limits to finance the certification stage of the SST development.

If the certification requirement is based on the PRC estimate of $604 million, instead of FAA's $446 million, the normal pattern of ability with dividend constraint of $613 million is just adequate. The $2,791 million afforded before taxes but at the February 1965 dividend rate provides a wide margin of flexibility.

Production Stage

This is defined as the stage following 100 hours of prototype flight when continuing production expenses are incurred. There is ample ability, as discussed earlier in this chapter, to finance this stage through conventional flows from the manufacturers, the airlines, and revolving working capital loans from banks to manufacturers. Essentially, there is a substitution of SST purchase dollars for subsonic jet dollars, so that the volume of availability for jets should be approximately adequate for the SST.

Annual cash flows purely for production, excluding development and profit thereon, are shown in Table A5.17 for SST markets of 200 and 400 planes (FAA estimates). For 200 planes, the production requirement peaks in the second year of delivery, 1973, at $714 million. The revenue, which is from 35 percent advance payments by airlines, peaks in 1974-5 at $1,020 million. The net annual outgo peaks in 1970 at $401 million. Cumulatively, the manufacturers' net outgo is at a maximum in 1971 at $1,049 million, and crosses to a surplus inflow in 1975.

For 400 planes, the annual outgo is at a maximum of $1,050 million in 1974, and the cumulative total at $1,981 million in 1975. Subtracting advance payments by airlines, the net annual peak outgo is $508 million in 1970, with the

Table A5.17. Production Cash Flows,[1] FAA Estimates for Boeing Lockheed, First Delivery in 1972
(million $)

Year	200 Planes						400 Planes					
	Outgo		Income[2]		Net		Outgo		Income[2]		Net	
	Ann.	Cum.	Ann.	Cum.	Ann.	Cum.	Ann.	Cum.	Ann.	Cum.	Ann.	Cum.
1965	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1966	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1967	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1968	84.4	84.4	0.	0.	- 84.4	- 84.4	100.4	100.4	0.	0.	- 100.4	- 100.4
1969	261.6	346.1	18.5	18.5	-243.2	- 327.6	309.0	409.5	18.7	18.7	- 290.3	- 390.8
1970	475.6	821.7	74.3	92.8	-401.2	- 728.8	580.8	990.2	73.2	91.9	- 507.6	- 898.4
1971	535.5	1357.1	215.4	308.2	-320.1	-1049.0	628.4	1618.6	226.0	317.8	- 402.4	-1300.8
1972	681.9	2039.1	762.4	1070.6	80.5	- 968.5	767 2	2385.9	830.5	1148.3	63.3	-1237.5
1973	714.1	2753.2	991.2	2061.7	277.1	- 691.4	966.0	3351.9	1216.3	2364.6	250.2	- 987.3
1974	664.6	3417.8	1018.1	3079.9	353.5	- 337.9	1050.5	4402.4	1929.8	4294.4	879.3	- 108.0
1975	596.2	4014.0	1019.9	4099.8	423.7	85.8	1006.0	5408.5	1981.2	6275.6	975.2	867.2
1976	498.1	4512.1	963.4	5063.2	465.3	551.1	932.8	6341.2	1968.8	8244.5	1036.1	1903.3
1977	316.7	4828.8	748.2	5811.4	431.5	982.6	757.1	7098.3	1828.9	10073.4	1071.8	2975.1
1978	141.0	4969.8	159.7	5971.1	18.7	1001.3	480.5	7578.8	1243.8	11317.2	763.3	3738.4
1979	139.9	5109.7	162.5	6133.6	22.6	1023.8	280.9	7859.7	321.9	11639.1	41.0	3779.4
1980	139.9	5249.7	162.5	6296.1	22.6	1046.4	279.8	8139.5	325.1	11964.3	45.4	3824.8
1981	139.9	5389.6	162.5	6458.6	22.6	1069.0	279.8	8419.3	325.1	12289.4	45.4	3870.1
1982	139.9	5529.6	162.5	6621.1	22.6	1091.5	279.8	8699.0	325.1	12614.5	45.4	3915.5
1983	139.9	5669.5	162.6	6783.7	22.7	1114.2	279.8	8978.8	325.1	12939.6	45.4	3960.8
1984	139.9	5809.4	162.6	6946.3	22.7	1136.9	279.8	9258.6	325.1	13264.8	45.4	4006.2
1985	139.9	5949.4	162.6	7108.9	22.7	1159.6	279.8	9538.4	325.1	13589.9	45.4	4051.5
1986	139.9	6089.3	162.6	7271.6	22.7	1182.2	279.8	9818.1	325.1	13915.0	45.4	4096.9
1987	133.5	6222.8	155.1	7426.7	21.6	1203.9	273.3	10091.5	317.8	14232.8	44.4	4141.3
1988	113.5	6336.4	134.4	7561.1	20.8	1224.7	253.4	10344.9	296.9	14529.7	43.5	4184.8
1989	88.2	6424.6	106.3	7667.3	18.0	1242.7	218.5	10563.4	257.7	14787.5	39.1	4224.0
1990	63.1	6487.7	77.0	7744.4	13.9	1256.6	168.3	10731.7	202.8	14990.1	34.5	4258.4
1991	37.9	6525.6	47.7	7792.1	9.8	1266.5	117.8	10849.5	144.3	15134.4	26.5	4284.9
1992	20.9	6546.5	27.9	7820.0	7.0	1273.5	67.5	10916.9	85.7	15220.1	18.3	4303.2
1993	0.	6546.5	2.8	7822.9	2.8	1276.3	29.4	10946.3	41.4	15261.5	12.0	4315.2
1994	0.	6546.5	0.	7822.9	0.	1276.3	0.	10946.3	3.2	15264.6	3.2	4318.4

[1]Based on manufacturing cost as validated by FAA, and profit margins as used by manufacturers in submissions to Department of Commerce. Excludes development costs and profits thereon.
[2]35% advance payments by airlines.

cumulative peak of $1,301 million in 1971. The crossover occurs in 1975.

A5.7 EFFECT OF HIGH AND LOW RANGE OF PROJECTIONS, 13 TRUNKLINES

While the effects of the high and low projections are traced in detail in Part II, they are summarized in Tables A5.18 and A5.19. For the high and low assumptions, see Table A5.12. By 1970, for total assets, revenues and debt, the range is between plus-or-minus 4 percent of the base projections. For earnings, however, the low is 35 percent, and the high 129 percent of the base. Thereafter the differences, being somewhat cumulative, tend to widen. For both the high and low assumptions, only the base estimates of manufacturers are included, because they are considered conservative in one case and minimal in the other.

High Assumptions

For 1965-9, under the normal pattern, availability goes up insignificantly, from $650 to $653 million, compared with a prototype requirement of $746 million. With dividend constraint, it rises from $837 to $921 million. For 1970-4, against a certification requirement of $446 million, $687 million is available under the lowest limit.

Low Assumptions

For 1965-9, cash availability under the normal pattern drops to $555 million from $650 million in the base assumptions. Since airline dividends drop below the 1964-5 level under the low assumptions, the dividend constraint is inapplicable, except for the $10 million increase produced for Boeing. Before taxes, however, the availability is $1,366, or almost twice requirements.

Table A5.18. High and Low as a Percent of Base Projections, 13 Trunklines, 1970, 1975 and 1980

Item	1970		1975		1980	
	High	Low	High	Low	High	Low
Total assets	104	96	114	88	124	80
Long term debt	104	102	115	104	126	103
Net profit[1]	129	35	142	27	156	21
Operating revenues	103	97	113	88	124	80

[1]Dividends are assumed to be 50% of net profits after taxes under all 3 sets of assumptions.

For 1970-4, no further availability of cash is obtained by raising the debt ratio of airlines to 55 percent because this limit is reached by carrying forward the increment of debt incurred in 1965-9 by raising the debt ratio to 50 percent. There is thus only the nominal availability of $60 and $70 million under the normal patterns of the manufacturers. The pre-tax upper limits of $735 and $1,092 million are substantially in excess of the certification requirement.

Evaluation, Low Assumptions

In evaluating availability under the low assumptions, several qualifications may be noted:

a. The cash availabilities for manufacturers are very conservative. For GE under the normal patterns cash availability is set at zero. Obviously GE could, and probably would, make substantial inputs of cash if awarded the SST engine contracts. The

Table A5.19. Limits of Cash Availability: Base, High and Low Assumptions for Boeing, GE and 13 Trunklines, 1965-79[1]

Pattern and assumptions	1965-9	1970-4	1975-9
1. Normal pattern			
a. Low	555	60	5,509
b. Base	650	613	6,653
c. High	653	687	8,549
2. Normal with cash dividend constraint			
a. Low	565	70	5,519
b. Base	837	1,116	7,530
c. High	921	1,457	9,986
3. Upper limit, cash dividend constraint			
a. Low	1,366	735	6,525
b. Base	2,106	2,791	9,894
c. High	2,357	3,625	13,383
4. Upper limit, no cash dividends			
a. Low	1,731	1,092	6,635
b. Base	2,516	3,201	10,304
c. High	2,767	4,035	13,793

[1]Because of the nature of the projections for Boeing and GE, they are included in the totals only as base estimates, the variations in assumptions being limited to the airlines. The manufacturer projections of 1965-75 have been applied to 1975-9. The normal patterns reflect debt ratios of 50% in 1969 and 55% in 1974.

5-year totals of 60 and 70 million dollars for Boeing are also minimal.

b. Airlines can draw on PPE for advance payments and deliveries, particularly during 1970-4.

A5.8 COMPARISON OF BASE PROJECTIONS FOR THE THIRTEEN AND THE FIVE AIRLINES

A detailed analysis and comparison of the range of projections for The Thirteen and The Five airline groups will be found in Part II. However, a summary comparison of key items in the base projections for 1970, 1975 and 1980, with 1964 as a reference, is shown here in Table A5.20. As a basic comparison, operating revenues of The Thirteen in 1964 were $3,768 million, and 145 percent of the $2,602 million of The Five.

PPE outlay for The Thirteen ranges from 159 percent to 177 percent of that for The Five.

Cash dividend payout is substantially lower for The Five, running 29 to 35 percent, versus 50 percent for The Thirteen.

Debt ratios in 1970 are about the same, at 42/43 percent. They are considerably lower for The Five in 1975 and 1980, due chiefly to lower cash dividend payouts.

A5.9 ROLE OF SUBCONTRACTORS

In the commercial aircraft manufacturing industry, the normal relationship is for the prime contractor to price on the basis of his estimate of the market, and for subcontractors to price their supply on the basis of their own estimates of the market. The prime contractor will shop for bids, with a good part of the difference in bids due to the

varying market estimates of the subcontractors. While there has been mention of plans in which prime contractors would have their subcontractors participate in financing the development of subsonic aircraft, inquiry among manufacturers has not revealed any basis for assuming a substantial deviation from the normal practice described above.

A5.10 ROLE OF INSTITUTIONAL LENDERS

It is expected that banks and other short-term lenders would enter the financing picture for the SST only at the production stage. The lender role would be primarily to provide a revolving working capital fund to finance the production cycle, as has been done conventionally for the manufacturers in the past.

In this frame of reference, the chief problem is the technical and economic uncertainty of the SST. By the time of certification, however, this will have been delimited considerably. Given progress payments by airlines, internal financing of the earliest stages without bank loans to manufacturers, and normal collateral, the situation seems manageable for banks. This would be particularly so under an orderly tempo of development, testing and deliveries.

Long-term borrowing of airlines and manufacturers is also expected to follow past patterns.

With regard to the magnitude of SST financing requirements, it may be noted that this would be close to the requirements for an equivalent subsonic fleet, since productivities per dollar of price for the two aircraft types are proximate. In this respect, the conventional financing patterns applicable to subsonic planes would also be applicable to the SST.[1]

Table A5.20. Comparison of Base Projections, Thirteen versus Five Airline Totals, 1970, 1975 and 1980, with 1964 as Reference

Item	1964[1]	1970	1975	1980
1. PPE outlay during year (13 versus 5)	134%	177%	159%	170%
2. Cash dividend payout as % of income (13 versus 5)	21/19	50/35	50/30	50/29
3. Long term debt ratio, % (13 versus 5)	59/57	42/43	45/27	42/22

[1]Estimated.

[1]Plans have been suggested from time to time under which SST development and production expense would be privately financed, but guaranteed by the U.S. Government. Since the collateral would be limited to the related SST tangible assets, this is essentially a variant of, and classified as, Government financing and risk-taking.

[redacted]

A6. BALANCE OF PAYMENTS EFFECTS

[redacted]

A6. BALANCE OF PAYMENTS EFFECTS

Over the past 13 years, export sales of aircraft and parts have contributed significantly to the favorable U.S. balance of trade. It is likely that this situation will continue, at least in the near-term, with the continuing sales of aircraft and parts for existing fleets, and with sales of new aircraft such as the Boeing 727 and the Douglas DC-9.

The supersonic transport programs, either our own or the Concorde, will have no effect on the present U.S. balance of payments. First-round deliveries to the Free World's airlines will largely be made during the decade 1970-1980. Our purpose here is to estimate the approximate impact on U.S. balance of payments of alternative programs, assuming various degrees of capture of the aircraft market.

A6.1 HISTORICAL PERSPECTIVE

The airlines periodically reequip their fleets with newer, more advanced aircraft, and these reequipment cycles place very large transient demands on the aircraft manufacturing industry. Production, and hence exports and imports, vary greatly from year to year. This extreme variability is evident in Figure A6.1, where the value of U.S. exports and imports of civilian aircraft and parts are shown. The detailed data may be found in Table A6.1. An attempt has been made to identify the various peaks of trade activity with the entry into the world market of specific new aircraft.

The United States has enjoyed a favorable balance on trade in aircraft. Cumulative total exports (1952-1964) amount to nearly $3.0 billions; cumulative total imports, to $0.4 billions. The relative importance of civilian aircraft is seen to be 1.3 to 1.7 percent of total merchandise exports, as shown in Table A6.2. These data indicate that, in the past 13 years, the airlines have not only refurbished their fleets, but greatly expanded them. In light of this unusual expansion, one might well question whether the period 1952-1964 should be regarded as typical, and hence useful as a guide to the future. A more typical market behavior may reflect a more slowly rising value of trade, and more accentuated peaks resulting from the less frequent entry of new aircraft into the market.

Note that sale of a new aircraft generally includes an associated sale of initial spare parts, together with the continuing sale of maintenance spares over its useful life. The value of initial spares amounts to about 25 percent of that of the aircraft; that of maintenance spares over a 15-year aircraft life, about 105 percent.

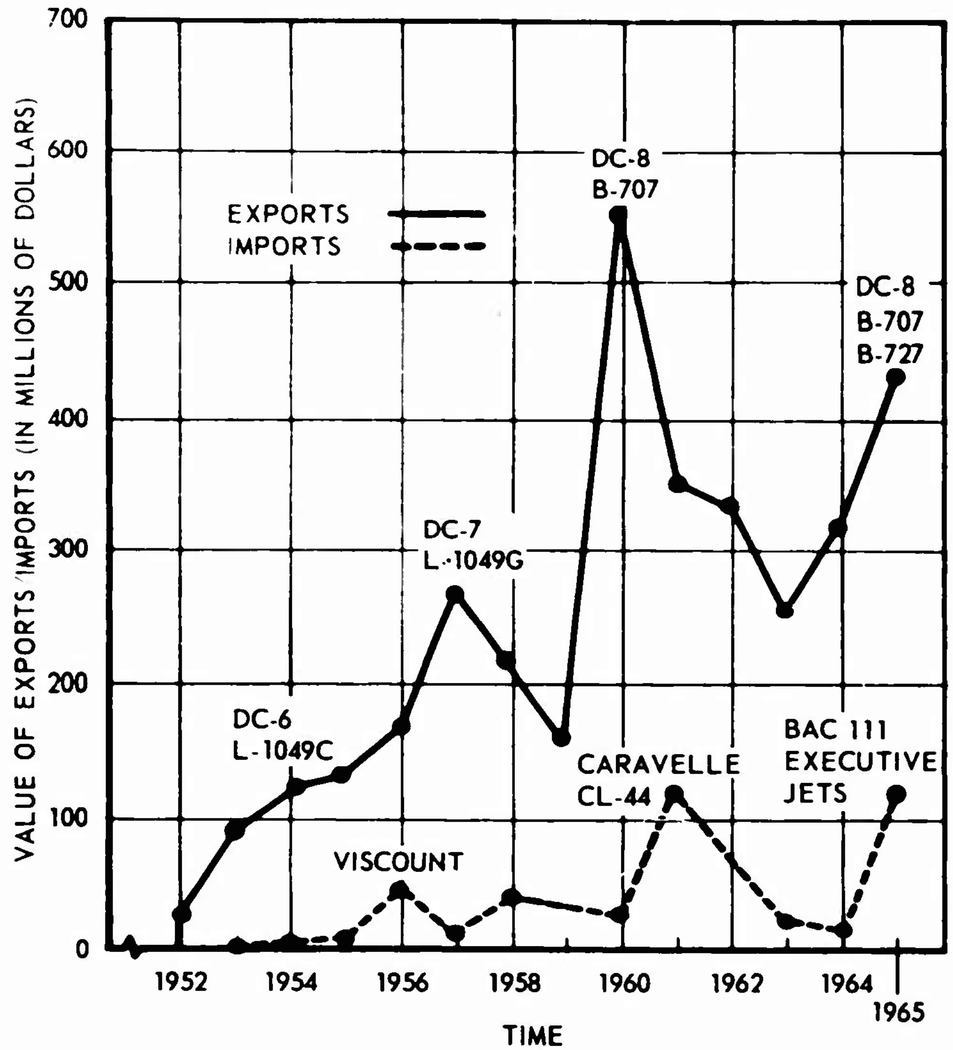
A6.2 POSSIBLE PROGRAM OUTCOMES

The impact of the supersonic transport on the U.S. balance of payments will depend on the extent to which:

a. supersonic aircraft may displace subsonic, and

b. the SST may be properly timed and more attractive than the Concorde.

If the air transport market grows at the base rate, there would be a requirement in 1980 for a seat-mile capacity equivalent to about 1900 current subsonic jets. The following program outcomes are considered in determining the range of possible balance of payments effects:



NOTE: DATA FOR 1952 TO 1963 REPRESENT ACTUALS; FOR 1964 AND 1965, ESTIMATES OF OFFICE OF BUSINESS ECONOMICS

Figure A6.1. Value of U.S. exports and imports of aircraft and parts, 1952–1965.

Table A6.1. U.S. Trade Balance - Civil Aircraft (Millions of Dollars)

Year	(Exports-excluding military)			
	Total civilian aircraft and parts	New civilian transport aircraft[1]	Imports of civilian aircraft and parts	Balance in aircraft trade (all positive)
1952	$ 27	$ 18	$ -	$ 27
1953	91	78	2	89
1954	121	87	1	120
1955	131	78	8	123
1956	170	128	48	122
1957	269	172	13	256
1958	217	144	41	176
1959	159	105	37	122
1960	551	473	27	524
1961	351	255	120	231
1962	334	239	74	260
1963	251	171	23	228
1964[2]	320	205	15	305
1965[2]	430	290	118	312

[1]Includes civilian transport aircraft in the 15-30,000 lb. class and over 30,000 lbs., with the heavier class accounting for a very large percent of the total. Omitted from this column is an unknown amount of spare engines and parts, which is included in the total column. Other differences between the first two columns are accounted for by smaller aircraft and by used aircraft of all sizes.

[2]Estimates for 1963, 1964, and 1965 by Office of Business Economics.

Source: Bureau of the Census, Report No. 410, "U.S. Exports of Domestic and Foreign Merchandise;" Report No. 110, "U.S. Imports of Merchandise for Consumption."

[redacted]

Table A6.2. The Importance of Civilian Aircraft Exports and Imports
(Millions of Dollars)

Year	Exports			Imports			Overall U.S. balance of payments
	Total merchandise	Civil aircraft	Percent aircraft of total	Total merchandise	Civil aircraft	Percent aircraft of total	
1952	13,319	27	0.2	10,838	-	-	-1,046
1953	12,281	91	0.7	10,990	2	-	-2,152
1954	12,799	121	0.9	10,354	1	-	-1,550
1955	14,280	131	0.9	11,527	8	0.1	-1,145
1956	17,379	170	1.0	12,804	48	0.4	- 935
1957	19,390	269	1.4	13,291	13	0.1	+ 520
1958	16,264	217	1.3	12,952	41	0.3	-3,529
1959	16,282	159	1.0	15,310	37	0.2	-3,743
1960	19,459	551	2.8	14,723	27	0.2	-3,925
1961	19,913	351	1.8	14,497	120	0.8	-2,370
1962	20,576	334	1.6	16,134	74	0.4	-2,203
1963	21,938	251	1.1	16,931	23	0.1	-2,644
1964(E)	24,800	320	1.3	18,600	15	0.1	-
1965(E)	26,000	430	1.7	20,200	118	0.6	-

Sources: Table A6.1 of this report. Data for exports and imports for 1952 to 1962 secured from Balance of Payments Statistical Supplement, U.S. Department of Commerce, Office of Business Economics, pp. 2-5. Estimated data for 1963 through 1965 secured from Office of Business Economics.

[redacted]

Case I ("Pure SST World") — The SST design is timely and excellent; the subsonic jets are displaced in virtually all the long-range markets; the Concorde program is terminated.

Case II ("Pure Subsonic World") — The SST Program is terminated; the Concorde design is poor and only a nominal number are produced; the long-range market is served primarily by a variety of subsonic jets—current, growth, and commercial CX-HLS.

Case III ("Supersonic World") — Both the SST and the Concorde designs are good; the subsonic jet is virtually displaced in the long-range market.

Case IV ("SST-Subsonic World") — The SST design is good; the Concorde design, poor; the current and growth subsonic jets continue to hold a good share of the aircraft market.

Case V ("Concorde—Subsonic World") — The SST Program is terminated; the Concorde design is excellent; the current and growth subsonic jets continue to hold a good share of the aircraft market.

The numbers of aircraft associated with these possible program outcomes are listed in Table A6.3. The unit costs for the various aircraft (listed in Table A6.4) are manufacturers' figures except for the Boeing 733-290, which are FAA-validated.

A6.3 SUMMARY OF RESULTS

The resulting values of aircraft production and trade are listed in Table A6.5. The extremes as to program outcomes (Cases I and V) range between a positive balance on trade in aircraft of $9.5 billions and a deficit balance of $7.8 billions. The more probable outcomes if the SST Program is continued (Cases III and IV) range between positive balances of $0.5 to $8.6 billions. Case II, in which the Concorde design is poor and the subsonics prevail, would show a positive balance on trade in aircraft of $6.4 billions.

Regardless of the choices made among U.S. program alternatives, the balance of payments impact will be distributed over at least twenty years (approximately 1970 to 1990), with perhaps 60 percent occurring in the first decade. Moreover, to the extent that the export aircraft are financed in the U.S., the effects on balance of payments will be further diffused over time. The impact on the overall U.S. balance of trade could be lessened by compensatory effects in other product areas in which we trade. Thus, a substantial success for the SST Program could increase U.S. national income, which would lead to increased U.S. imports of a variety of foreign-made products. Conversely, a substantial success for the Concorde could have analogous compensatory effects which would tend to diminish its impact on U.S. balance of payments.

Table A6.3. Assumed Numbers of Aircraft in 1980

Cases	Subsonic			Supersonic	
	Boeing 707-320B	Growth subsonic	Commercial CX-HLS	Boeing 733-290	Concorde
Pure SST	170	0	0	600	0
Pure Subsonic	500	435	190	0	60
Supersonic	170	0	0	400	460
SST-Subsonic	340	250	0	400	60
Concorde-Subsonic	420	250	0	0	910

Table A6.4. Unit Costs for Various Aircraft

	Airframe	Engine	Aircraft
707-320B	$ 5,925,800	$ 285,500	$ 6,960,000
Growth Subsonic	8,260,000	310,000	9,500,000
Commercial CX-HLS	14,000,000	500,000	16,000,000
733-290	19,300,000	1,017,000	23,400,000
Concorde	10,700,000	700,000	13,500,000

[redacted]

Table A6.5. Value of Aircraft Production and Trade (1965-1980) for Various Assumptions as to Program Outcome

Cases	Value of aircraft production (in billions $)						Value of trade in aircraft (in billions $)		
	Boeing 707-320B	Growth subsonic	Commercial CX-HLS	Boeing 733-290	Concorde	World total	U.S. exports	U.S. imports	Balance on aircraft
Pure SST	2.7	—	—	21.0	—	23.7	9.5	—	9.5
Pure Subsonic	7.2	6.6	4.6	—	1.7	20.1	7.4	1.0	6.4
Supersonic	2.7	—	—	14.6	10.6	27.9	6.9	6.4	0.5
SST-Subsonic	5.2	4.3	—	14.6	1.7	25.8	9.6	1.0	8.6
Concorde-Subsonic	6.4	4.3	—	—	20.2	30.9	4.3	12.1	-7.8

[redacted]